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इलैक्ट्रॉनी उपस्करों में प्रयुक्त विभवमापी

भाग 1 सामान्य विशिष्टि

Indian Standard

POTENTIOMETERS FOR USE IN ELECTRONIC EQUIPMENT

PART 1 GENERIC SPECIFICATION

ICS 31.040.20

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

August 2000

Price Rs. 240.00

Resistors and Capacitors for Electronic Equipment Sectional Committee, LTD 14

NATIONAL FOREWORD

This Indian Standard which is identical with IEC 393-1/IEC QC 410000 (1989) 'Potentiometers for use in electronic equipment — Part 1 : Generic specification' [along with Amendment No. 1 (1992)] issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of Resistors and Capacitors for Electronic Equipment Sectional Committee and approval of the Electronics and Telecommunication Division Council.

The text of the IEC standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

Amendment No.1 (1992) to the above International Standard has been printed at the end.

Only the English language text in the International Standard has been retained while adopting it in this standard.

This standard is intended primarily for use under IECQ system.

CROSS REFERENCES

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 27-1 (1971) Letter symbols to be used in electrical technology — Part 1 : General	IS 3722 (Part 1) : 1983 Letter symbols and signs used in electrical technology : Part 1 General guidance on symbols and subscripts	Not Equivalent
IEC 50 International Electrotechnical Vocabulary	IS 1885 (Part 46) : 1977 Electrotechnical vocabulary : Part 46 Resistors	do
IEC 62 (1974) Marking codes for resistors and capacitors	IS 8186 : 1976 Marking codes for values and tolerance of resistors and capacitors	do
IEC 63 (1963) Preferred number series for resistors and capacitors	IS 824 : 1965 Preferred values for resistors and capacitors	do
IEC 68-1 (1978) Basic environmental testing procedures — Part 1 : General	IS 9000 (Part 1) : 1988 Basic environmental testing procedures for electronic and electrical items : Part 1 General	do
IEC 68-2-1 (1974) Tests A : Cold	IS 9000 (Part 2/Sec 1) : 1977 Part 2 Cold test, Section 1 General	do
IEC 68-2-2 (1974) Tests B : Dry heat	IS 9000 (Part 3/Sec 1) : 1977 Part 3 Dry heat, Section 1 General	do
IEC 68-2-3 (1969) Test Ca : Damp heat, steady state	IS 9000 (Part 4) : 1979 Part 4 Damp heat (steady state)	do

(*Continued on third cover*)

Indian Standard
POTENTIOMETERS FOR USE IN ELECTRONIC EQUIPMENT

PART 1 GENERIC SPECIFICATION

SECTION ONE - SCOPE

1 Scope

This standard is applicable to all types of resistive potentiometers, including lead-screw actuated types, presets, multi-turn units, etc. to be used in electronic equipment.

It establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications for Qualification Approval and Quality Assessment Systems for electronic components.

It has been mainly written, and the test methods described, to conform with the widely used single turn rotary potentiometer with a control spindle.

For other types of potentiometers:

- the angle of rotation may be several turns;
- the reference to a control spindle shall apply to any other actuating device;
- the angular rotation shall be taken to mean mechanical travel of the actuating device;
- a value for force shall be prescribed instead of a value for torque if the actuating device moves in a linear instead of a rotary manner.

These alternative prescriptions will be found in the sectional or detail specification.

When a component is constructed as a variable resistor, i.e. as a 2-terminal device, the detail specification shall prescribe the modifications required in the standard tests.

SECTION TWO - GENERAL

2. General

2.1 Related documents

IEC Publications:

Publication 27-1 (1971)	Letter Symbols to be Used in Electrical Technology. Part 1: General.
Publication 50	International Electrotechnical Vocabulary (I.E.V.).
Publication 62 (1974)	Marking Codes for Resistors and Capacitors.
Publication 63 (1963)	Preferred Number Series for Resistors and Capacitors. Amendment No. 1 (1967) Amendment No. 2 (1977)
Publication 68	Basic Environmental Testing Procedures.
Publication 68-1 (1978)	Part 1: General.
Publication 68-2-1 (1974)	Tests A: Cold
68-2-1A (1976)	First supplement.
Publication 68-2-2 (1974)	Tests B: Dry heat
68-2-2A (1976)	First supplement.
Publication 68-2-3 (1969)	Test Ca: Damp Heat, Steady State. Amendment No. 1 (1984).
Publication 68-2-6 (1970)	Test Fc: Vibration (sinusoidal). Amendment No. 2 (1985).
Publication 68-2-13 (1966)	Test M: Low Air Pressure.
Publication 68-2-14 (1974)	Test N: Change of Temperature.
Publication 68-2-17 (1968)	Test Q: Sealing.
Publication 68-2-20 (1979)	Test T: Soldering.
Publication 68-2-21 (1983)	Test U: Robustness of Terminations and Integral Mounting Devices. Amendment No. 1 (1985)
Publication 68-2-27 (1972)	Test Ea: Shock.
Publication 68-2-29 (1968)	Test Eb: Bump.

Publication 68-2-30 (1980)	Test Db: Damp Heat, Cyclic (12 + 12-hours cycle).
Publication 68-2-45 (1980)	Test XA and guidance: Immersion in cleaning solvants.
Publication 117	Recommended Graphical Symbols.
Publication 390 (1972)	Dimensions of Spindle Ends for Manually Operated Electronic Components.
Publication 410 (1973)	Sampling Plans and Procedures for Inspection by Attributes.
Publication QC 001001 (1986)	Basic Rules for the IEC Quality Assessment System for Electronic Components (IECQ).
Publication QC 001002 (1986)	Rules of Procedure for the IEC Quality Assessment System for Electronic Components (IECQ).

ISO Standards:

ISO 3 (1973)	Preferred Numbers - Series of Preferred numbers.
ISO 497 (1973)	Guide to the Series of Preferred Numbers and of Series Containing more Rounded Values of Preferred Numbers.
ISO 1000 (1973)	SI Units and Recommendations for the Use of their Multiples and of Certain Other Units.

Note. -The above references apply to the current editions except for IEC Publication 68, for which the referenced edition shall be used.

2.2 Units, symbols and terminology

2.2.1 General

Units, graphical symbols, letter symbols and terminology shall, whenever possible, be taken from the following publications:

- ISO Standard 1000
- IEC Publication 27
- IEC Publication 117
- IEC Publication 50

When further items are required they shall be derived in accordance with the principles of the documents listed above.

2.2.2 Type

A group of components having similar design features and the similarity of whose manufacturing techniques enables them to be grouped together either for qualification approval or for quality conformance inspection.

They are generally covered by a single detail specification.

Notes 1. -Components described in several detail specifications may, in some cases, be considered as belonging to the same type and may therefore be grouped together for qualification approval and for quality conformance inspection.

2. -Mounting accessories are ignored provided they have no significant effect upon the test results.

2.2.3 Style

A sub-division of a type, generally based on dimensional factors.

A style may include several variants, generally of a mechanical order.

2.2.4 Grade

A term to indicate additional general characteristics concerning the intended application e.g. long life applications.

The term "grade" may only be used in combination with one or more words (e.g. long-life grade) and not by a single letter or number.

Figures to be added after the term "Grade" should be arabic numerals.

2.2.5 Variant

A sub-division within a style having specific dimensions for some part of its construction, e.g. terminations, spindle flats or length.

2.2.6 Family (of electronic components)

A group of electronic components which predominantly displays a particular physical attribute and/or fulfils a determined function.

2.2.7 Sub-family (of electronic components)

A group of components within a family manufactured by similar technological methods.

2.2.8 Category temperature range

The range of ambient temperatures for which the potentiometer has been designed to operate continuously; this is defined by the temperature limits of its appropriate category.

2.2.9 Upper category temperature

The maximum ambient temperature for which a potentiometer has been designed to operate continuously at that portion of the rated dissipation which is indicated in the category dissipation (See Sub-clause 2.2.14).

2.2.10 Lower category temperature

The minimum ambient temperature for which a potentiometer has been designed to operate continuously.

2.2.11 Critical resistance

That resistance value at which the rated voltage is equal to the limiting element voltage. Below the critical resistance the maximum voltage which may be applied across the terminations of a potentiometer is the rated voltage. Above that value the maximum voltage is the limiting element voltage (See Sub-clauses 2.2.13, 2.2.15 and 2.2.16).

2.2.12 Rated resistance

The rated resistance is the resistance value marked upon the potentiometer.

2.2.13 Rated dissipation

The maximum allowable dissipation between terminations a and c (see Sub-clause 2.2.30) of a potentiometer at an ambient temperature of 70 °C under the conditions of the electrical endurance test at 70 °C which will result in a change in resistance not greater than that specified for that test.

Note. -In practice the dissipation is modified by the following conditions:

-For high values of resistance the limiting element voltage (Sub-clause 2.2.16) may prevent the rated dissipation being attained.

-For the dissipation at temperatures other than 70 °C, reference should be made to the rating graphs in the relevant detail specification.

-For situations where only terminations a and b or b and c are being used and the control spindle is set at an angle less than 100% of the effective electrical travel. In this case the limiting moving contact current (Sub-clause 2.2.18) should also be taken into account.

2.2.14 Category dissipation

The maximum allowable dissipation under continuous load at an ambient temperature equal to the upper category temperature and is normally expressed as a percentage of the rated dissipation.

Note. -The category dissipation may be zero.

2.2.15 Rated voltage

That d.c. or a.c. r.m.s. voltage calculated from the square root of the product of the rated resistance and the rated dissipation.

Note. -At high values of resistance, the rated voltage may not be applicable because of the size and construction of the potentiometer (see Sub-clauses 2.2.11, 2.2.13 and 2.2.16)

2.2.16 Limiting element voltage

The maximum d.c. or a.c. r.m.s. voltage which may be applied across the element of a potentiometer.

When the term "a.c. r.m.s. voltage" is used in this specification the peak voltage shall not exceed 1.42 times the r.m.s. value.

Note. -This voltage shall only be applied to potentiometers when the resistance value is equal to or higher than the critical value.

2.2.17 Isolation voltage

The maximum peak voltage under continuous operating conditions which may be applied between the potentiometer terminations and other external conducting parts connected together.

The value of the isolation voltage shall be not less than 1.42 times the limiting element voltage at normal air pressure. Under conditions of low air pressure the value of the isolation voltage will be less and shall be given in the detail specifications.

2.2.18 Limiting moving contact current

The maximum current that may be passed between the resistive element and the moving contact.

2.2.19 Variation of resistance with temperature

The variation of resistance with temperature can be expressed either as a temperature characteristic or as a temperature coefficient as defined below:

2.2.19.1 Temperature characteristic of resistance

The maximum reversible variation of resistance produced over a given temperature range within the category temperature range. It is expressed normally as a percentage of the resistance related to a reference temperature of 20 °C.

Temperature characteristic of resistance = $\frac{\Delta R}{R}$

where:

ΔR is the change in resistance between the two specified ambient temperatures.

R is the resistance value at the reference temperature.

2.2.19.2 Temperature coefficient of resistance (α)

The relative variation of resistance between two given temperatures (mean coefficient), divided by the difference in temperature producing it. It shall preferably be expressed in parts per million per °C. (10^{-6}/°C).

$$\alpha = \frac{R_2 - R_1}{R_1 . \Delta\theta}$$

where:

$\Delta\theta$ is the algebraic difference, in degrees Celsius, between the reference temperature and the specified ambient temperatures.

Note. -It should be noted that use of the term does not imply any degree of linearity for this function, nor should any be assumed.

2.2.20 Visible damage

Visible damage which reduces the usability of the potentiometer for its intended purpose.

2.2.21 Potentiometer

A component for use as a voltage divider with three terminations of which two are connected to the ends of a resistive element and the third to a moving contact which can be moved mechanically along the resistive element.

2.2.22 Pre-set or trimmer potentiometer

A potentiometer designed for relatively infrequent adjustment.

2.2.23 Lead-screw actuated potentiometer

A potentiometer having a lead-screw as multi-turn actuating device.

2.2.24 Ganged potentiometers

Potentiometers consisting of two or more sections operated by a common spindle.

2.2.25 Dual potentiometers

Potentiometers consisting of two sections operated independently by concentric spindles.

2.2.26 Spindle sealed potentiometer

A potentiometer in which a spindle seal is provided to prevent particles and fluid from passing from the exterior of the potentiometer to the interior by way of the spindle bearing. (see Fig. 1).

2.2.27 Spindle sealed and panel sealed potentiometer

A potentiometer in which a spindle seal and a panel seal is provided to prevent particles and fluid from entering any equipment in which this potentiometer is mounted. (see Fig. 2).

2.2.28 Container sealed potentiometer

A potentiometer in which a spindle seal is provided and the container housing of the potentiometer is designed to prevent particles and fluid from passing from the exterior of the potentiometer to the interior. (see Fig. 3).

In some cases a panel seal may additionally be provided.
Such a potentiometer is called a "fully sealed potentiometer" (see Fig. 4).

2.2.29 Direction of rotation

Rotation is defined as clockwise or anti-clockwise when viewing the face of the potentiometer which includes the means of actuation. When doubt exists, the reference face shall be marked in accordance with the detail specification.

2.2.30 Designation of terminations

The preferred designation of the three terminations of the potentiometer is:

- a is the end termination electrically nearest to the moving contact with the spindle set fully anticlockwise as defined in Sub-clause 2.2.29;
- b is the termination of the moving contact;
- c is the other end termination.

The numerals 1, 2 and 3 or colours yellow, red and green, may be used as alternatives to a, b and c respectively. When terminations are marked the marking shall be in accordance with this clause. Additional letters, numbers or colours for other terminations shall be allocated in the relevant specification.

2.2.31 Variable resistor

A resistor with a permanent contact at one end of the resistive element and a second contact which can be moved along the resistive element, causing a change in resistance.

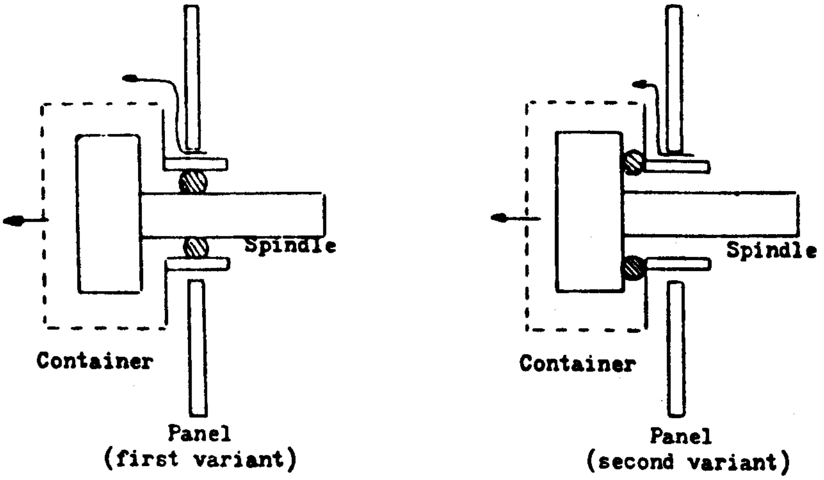


Fig. 1: Spindle sealed potentiometer

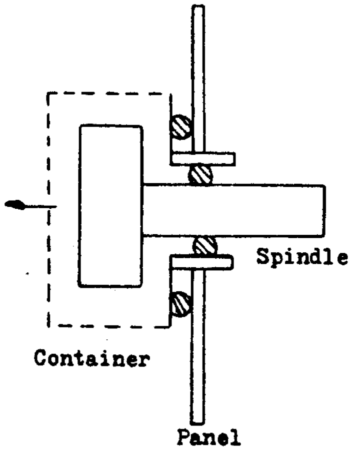


Fig. 2: Spindle & panel sealed potentiometer

Unsealed paths are shown thus

←

Sealed surfaces are shown thus

——

Unsealed surfaces are shown thus

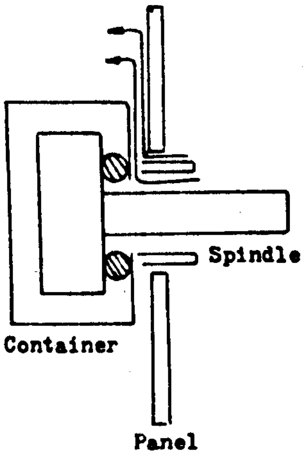


Fig. 3: Container sealed potentiometer

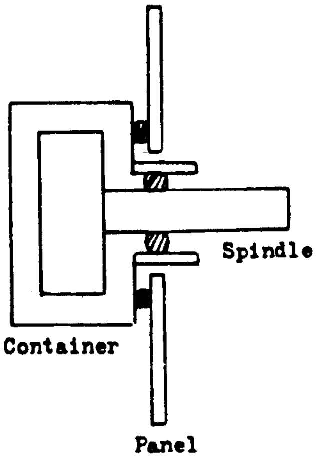


Fig. 4: Fully sealed potentiometer

2.2.32 Moving contact

The contact of the potentiometer which moves along the resistive element.

2.2.33 Tap

A fixed electrical connection made to the resistive element.

2.2.34 Track

The contact path of the moving contact on the resistive element.

2.2.35 Declutching device

That device which allows continuous rotation of the actuating device after the moving contact has reached either end of the resistive element.

2.2.36 Number of turns (of an actuating device)

The total number of times the actuating device completes (or nearly completes) 360° of movement in covering the total mechanical travel.

2.2.37 Resistance law

The relationship of the measured resistance value between terminations a and b or of the output ratio $\frac{U_{ab}}{U_{ac}}$ to the mechanical position of the moving contact.

2.2.37.1 Common potentiometer laws are classified a follows

1) Linear law: Law A (Fig.5)

2) Logarithmic law: Law B (Fig.6)

3) Inverse logarithmic law: Law C (Fig.7)

The sectional or detail specifications may permit, and prescribe the tolerances for, a rate of change of resistance near to the end of the effective travel less than that required by the prescribed law. It may also permit, and prescribe the tolerances for, approximations to the law of the form shown dotted in Figures 6 and 7.

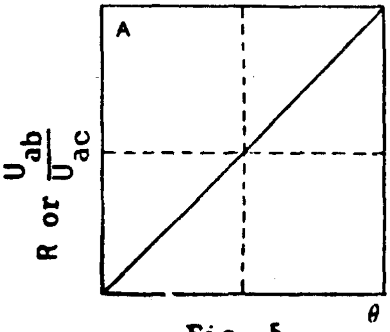


Fig. 5

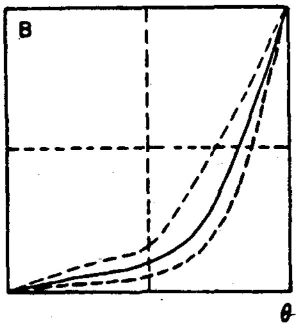


Fig. 6

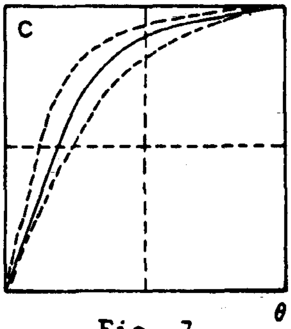


Fig. 7

θ: Angle of rotation (clockwise)

2.2.37.2 Laws other than the widely used Laws A, B and C listed in 2.3.37.1 (for example sine or co-sine) may be required for special applications. The law will then be prescribed in the sectional or detail specification.

2.2.38 Cycle of operation

For single and multi-turn potentiometers, a cycle of operation is defined as the travel of the moving contact from one end of the resistive element to the other and back.

For continuously rotating potentiometers, a cycle of operation is defined as two revolutions of 360°, in the same direction, of the moving contact.

2.2.39 Shorted-segment

A portion of the resistive element over which the output ratio remains constant within specified limits as the moving contact traverses the segment with a specified load resistance.

2.2.40 Terminal resistance

Terminal resistance is the minimum resistance which can be obtained between the termination connected to the moving contact b, and any other termination (see Sub-clause 2.2.30).

2.2.41 Residual resistance

The residual resistance is the resistance obtained between the end termination, a or c, and the termination of the moving contact b, when the moving contact is set against the relevant end stop (see Sub-clause 2.2.30).

Note. -When there is no sharp change of resistance between the end stop and the point where the minimum effective resistance is observed the residual resistance, the terminal resistance and the minimum effective resistance become the same. The lowest resistance value need not correspond with the mechanical end stop.

2.2.42 Load resistance (R_L) (see Fig.9)

The external resistance as seen by the output voltage (connected between the moving contact and either termination a or c).

2.2.43 Total applied voltage (U_{ac}) (see Fig. 8)

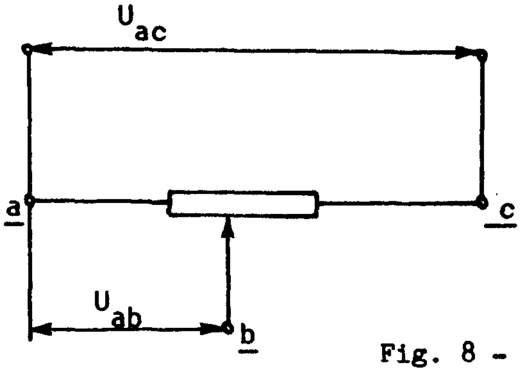
The voltage applied between input terminations, e.g. the voltage applied between input terminations a and c.

2.2.44 Output voltage (U_{ab}) (see Fig. 8)

The voltage between termination b and the specified reference point. Unless otherwise specified, the specified reference point is termination a.

2.2.45 Output ratio (see Fig.8)

The ratio of the output voltage U_{ab} to the total applied voltage U_{ac}.



$$\text{Output ratio} = \frac{U_{ab}}{U_{ac}}$$

Fig. 8 - Output ratio

It is normally expressed as a percentage of the total applied voltage.

2.2.46 Minimum output ratio

The ratio of the minimum voltage value which can be obtained between the moving contact termination and one or other of the end terminations to a fixed voltage applied between the end terminations.

2.2.47 Attenuation

The reciprocal of the output ratio. It is normally expressed as $20 \log \frac{U_{ac}}{U_{ab}}$ dB.

2.2.48 Loading error (see Fig.9)

The difference between the output ratio with an infinite load resistance and the output ratio with a specified finite load resistance at any spindle position as long as it is the same position for both output ratio measurements.

Note. -Minimizing the loading error, by compensating the resistance element to give the desired output with a specified load resistance, is referred to as "load compensation".

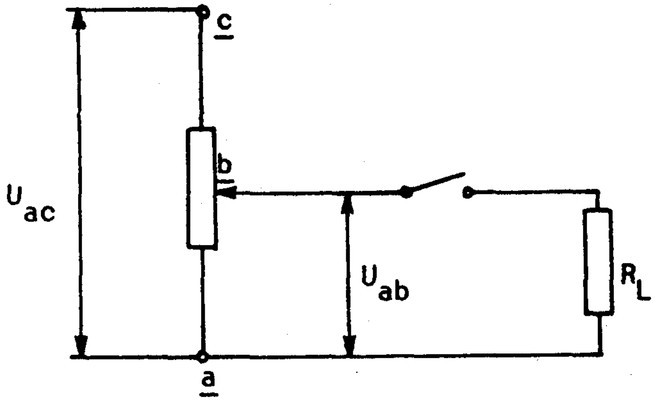


Fig. 9 - Loading error

2.2.49 Resistance/travel relationships

The following definitions apply to two general constructions:

1) Potentiometers fitted with end stops or with declutching devices.

2) Single turn rotary potentiometers not fitted with end stops or declutching devices.

The amount of travel may be expressed in degrees, number of turns or millimetres.

For other constructions the detail specification shall redefine the terms or definitions.

Note. -The alternative terms given in parentheses in Sub-clauses 2.2.49.1, 2.2.49.3 and 2.2.49.4 are included for information only.

2.2.49.1 Total mechanical travel (total mechanical rotation) (see Fig. 10)

In (1) above, the total mechanical travel is the value of the movement of the actuating device while the moving contact traverses the whole of its function between the two end stops or, the two positions at which the declutching device operates.

In (2) above, the total mechanical is travel 360°.

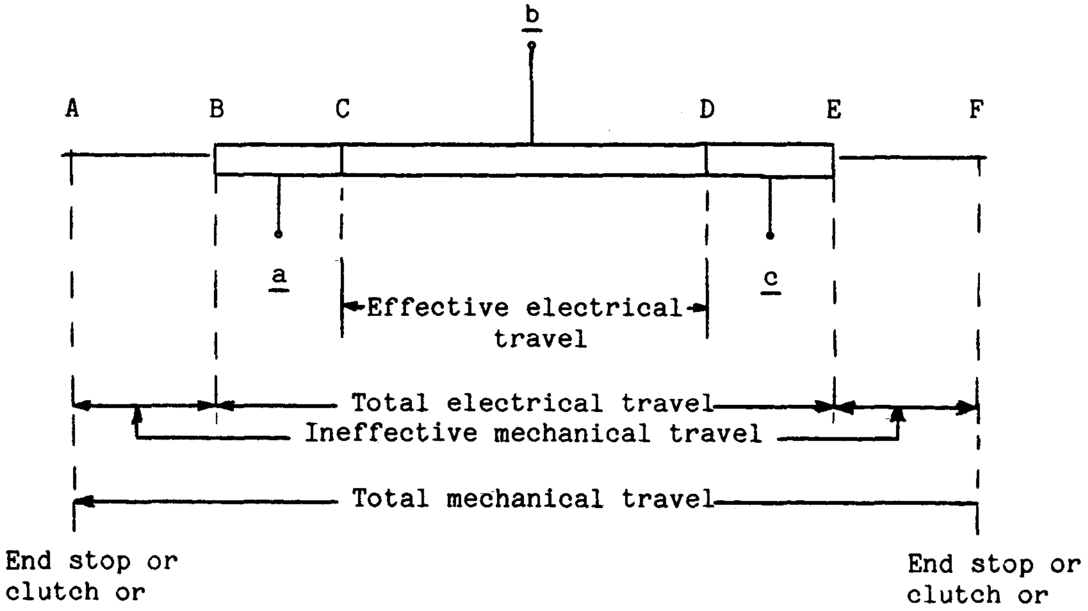

b
A
B
C
D
E
F
a
c
Effective electrical travel
Total electrical travel
Ineffective mechanical travel
Total mechanical travel
End stop or clutch or 0°
End stop or clutch or 360°

Fig. 10

2.2.49.2 Total electrical travel (see Fig. 10)

The amount of travel of the actuating device between two end positions during which there should not normally be any interruption in contact between the moving contact and the resistive element.

Note. -In (1) above, the end positions usually coincide with the end stops or the positions at which the declutching device operates, and the total electrical travel is therefore the same as the total mechanical travel.

2.2.49.3 Effective electrical travel (angle of effective electrical rotation)

The amount of travel of the actuating device necessary to move the moving contact in such a manner that the resistance changes as prescribed by the specified resistance law.

Note. - For some constructions of potentiometer, the effective electrical travel may be the same as the total electrical travel.

2.2.49.4 Ineffective mechanical travel (angle of ineffective mechanical rotation) (see Fig. 10)

That part of the mechanical travel where the continuity between the moving contact and the resistance element cannot be guaranteed. It is equal to the difference between the total mechanical travel and the total electrical travel.

2.2.49.5 Total resistance

The total resistance is the resistance between terminations a and c (R_{ac}) when measured as described in Sub-clause 4.6.

2.2.49.6 Effective resistance

That portion of the total resistance over which the resistance changes in the manner prescribed by the specified resistance law.

2.2.49.7 Minimum effective resistance

The resistance value, at each end of the effective electrical travel, between termination b and the nearer end termination a or c (see Sub-clause 4.4.6), normally expressed as a percentage of the total resistance.

2.2.49.8 Continuity

The maintenance of electrical contact between the moving contact and the resistive element as a function of the mechanical travel of the moving contact.

2.2.49.9 Conformity (see Fig.11)

The maximum measured difference between the actual and the specified resistance law when it is expressed as a percentage of total resistance or total voltage applied.

Note. -Conformity may be expressed in different ways and must be clearly specified in the detail specification. Some methods of expressing conformity are shown in the following Sub-clauses.

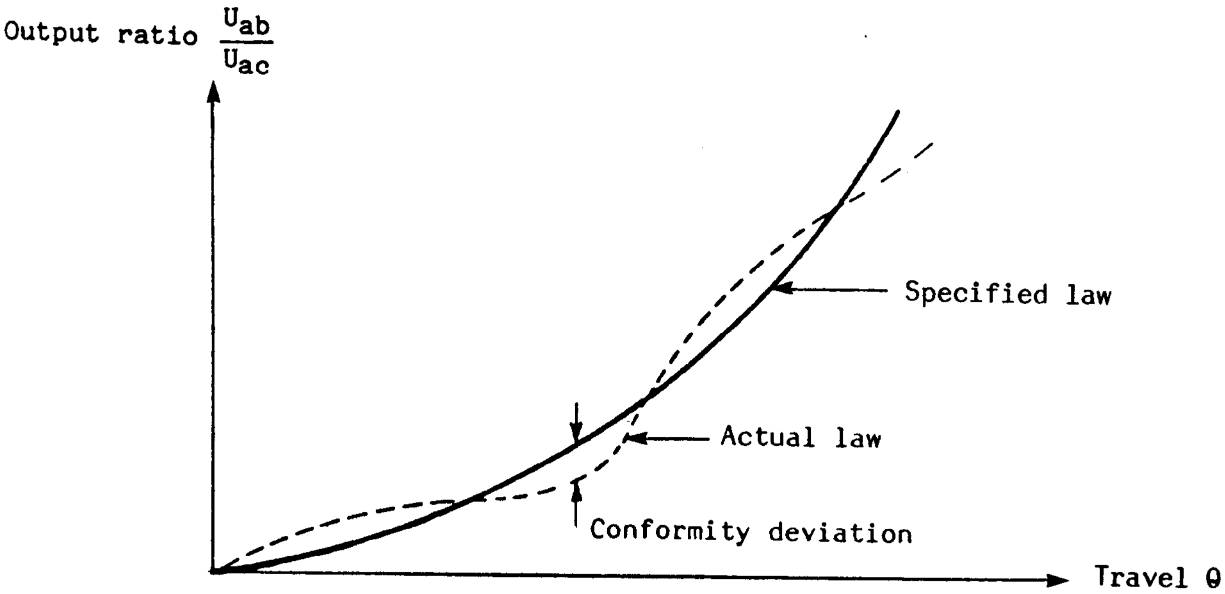


Fig. 11 - Conformity

2.2.49.10 Absolute conformity (see Fig.12)

The conformity measured over the specified effective electrical travel and is expressed as the maximum deviation of the actual from the specified resistance law.

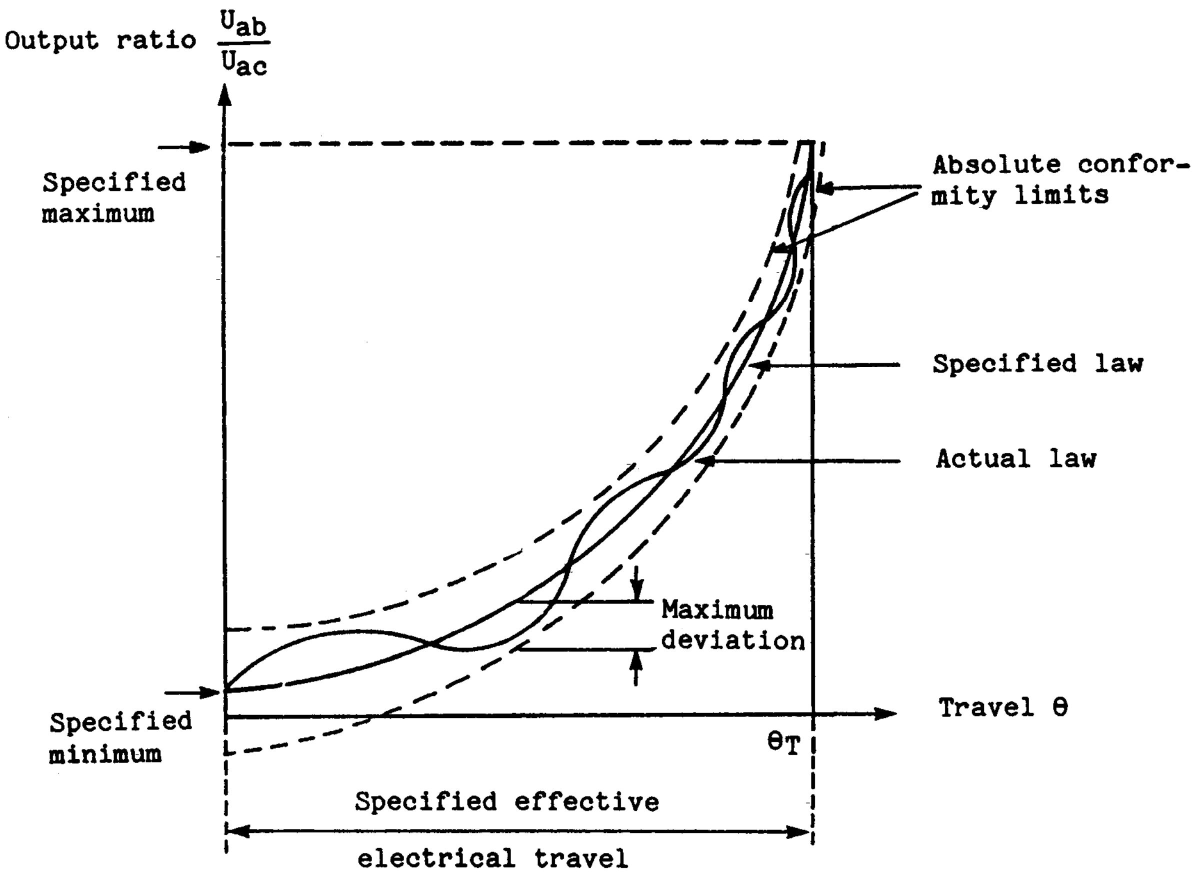


Fig. 12: Absolute conformity

2.2.49.11 Linearity (see Fig. 13)

The specific type of conformity when the specified law or output ratio is shown as a straight line.

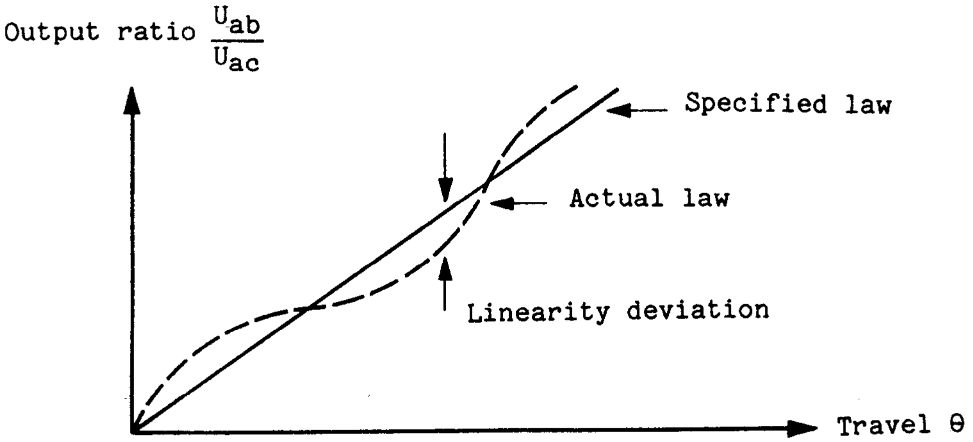


Fig. 13: Linearity

2.2.49.12 Independent linearity (best straight line) (see Fig.14)

The specific type of conformity when the maximum vertical deviation, expressed as a percentage of the total applied voltage, of the actual law from a straight reference line with its slope and position is chosen to minimise deviations over the effective electrical travel, or any specified portion thereof.

Note. -Requirements for minimum and maximum output ratio, when specified, will limit the slope and position of the reference line.

MATHEMATICALLY: $\frac{U_{ab}}{U_{ac}} = P(\frac{\theta}{\theta_A}) + Q \pm C$

where:

P is the unspecified slope, Q is the unspecified intercept at $\theta = 0$, and where P and Q are chosen to minimise C but are limited by the output ratio requirement and θ_A is the amount of effective electrical travel.

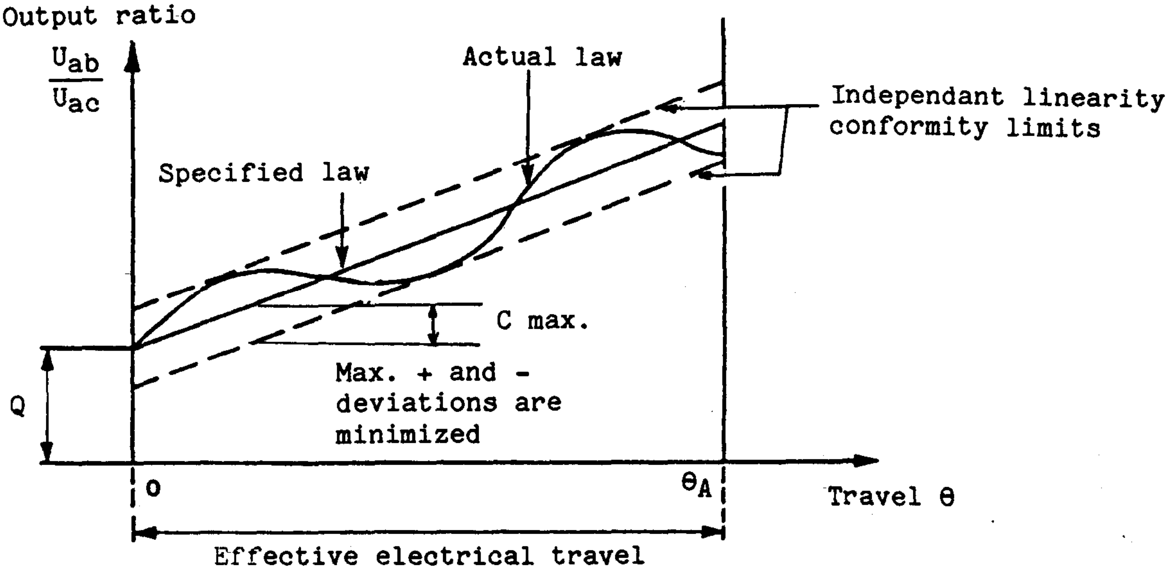

Output ratio
$\frac{U_{ab}}{U_{ac}}$
Actual law
Independant linearity conformity limits
Specified law
C max.
Max. + and - deviations are minimized
Q
0
θ_A
Travel θ
Effective electrical travel

Fig. 14 - Independent linearity

2.2.49.13 Zero based linearity (see Fig.15) (for wirewound potentiometers only)

The specific type of conformity when the maximum vertical deviation, expressed as a percentage of total applied voltage, of the actual law from a straight reference line drawn through the specified minimum output ratio extended over the effective electrical travel, with its slope chosen to minimise the maximum deviations. Any specified requirement for maximum output ratio may limit the possibility to change the slope of the reference line. Unless otherwise specified, the specified minimum output ratio will be zero.

MATHEMATICALLY: $\frac{U_{ab}}{U_{ac}} = P(\frac{\theta}{\theta_A}) + B \pm C$

where:

P is the unspecified slope limited by the end voltage requirement at the maximum output ratio end; θ_A = amount of effective electrical travel.

Unless otherwise specified: B = 0

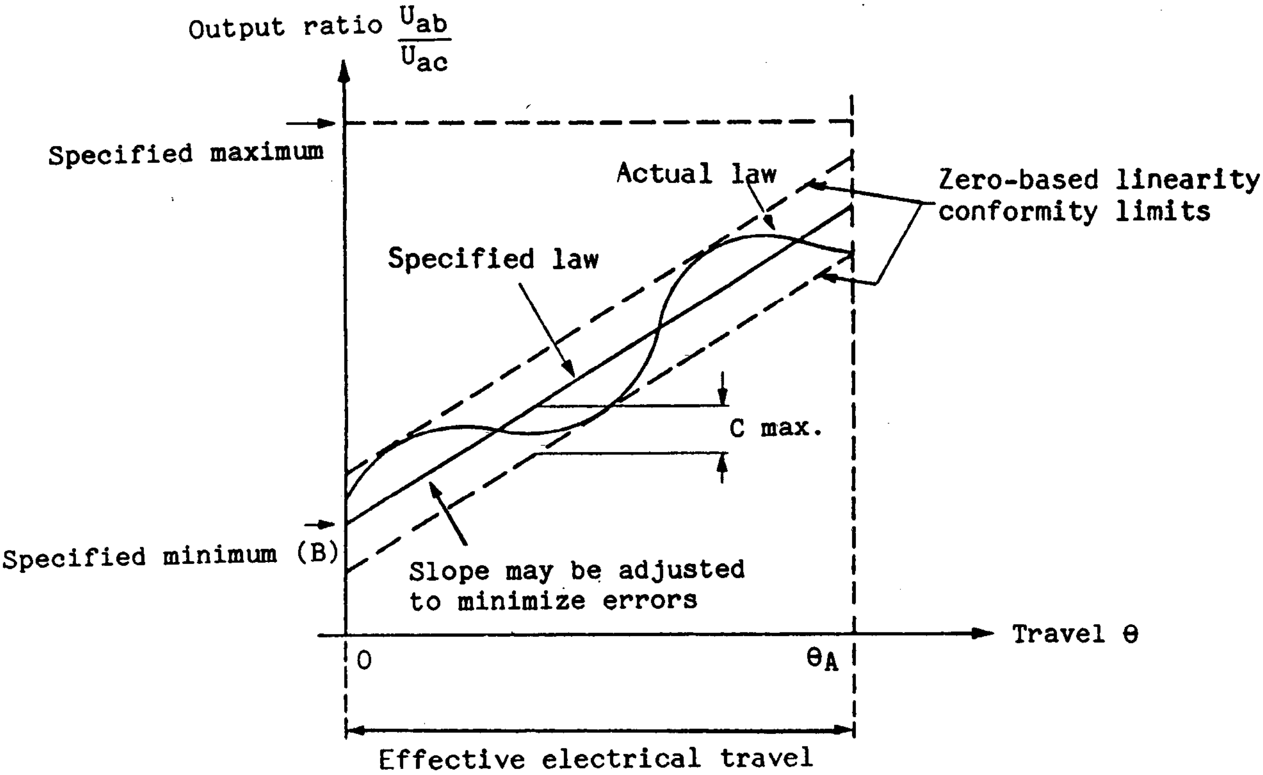

Output ratio $\frac{U_{ab}}{U_{ac}}$
Specified maximum
Actual law
Zero-based linearity conformity limits
Specified law
C max.
Specified minimum (B)
Slope may be adjusted to minimize errors
Travel θ
0
θ_A
Effective electrical travel

Fig.15 - Zero-based linearity

2.2.49.14 Absolute linearity (see Fig.16)

The specific type of conformity where the maximum vertical deviation, expressed as a percentage of the total applied voltage, of the actual law from a straight reference line drawn through the specified minimum and maximum output ratios which are separated by the specified effective electrical travel. Unless otherwise specified, minimum and maximum output ratios are respectively zero and 100% of the total applied voltage.

MATHEMATICALLY: $\frac{U_{ab}}{U_{ac}} = A(\frac{\theta}{\theta_T}) + B \pm C$

where:

A is the given slope, B is the given intercept at $\theta = 0$;
θ_T is the total specified effective electrical travel.
Unless otherwise specified A = 1 and B = 0.

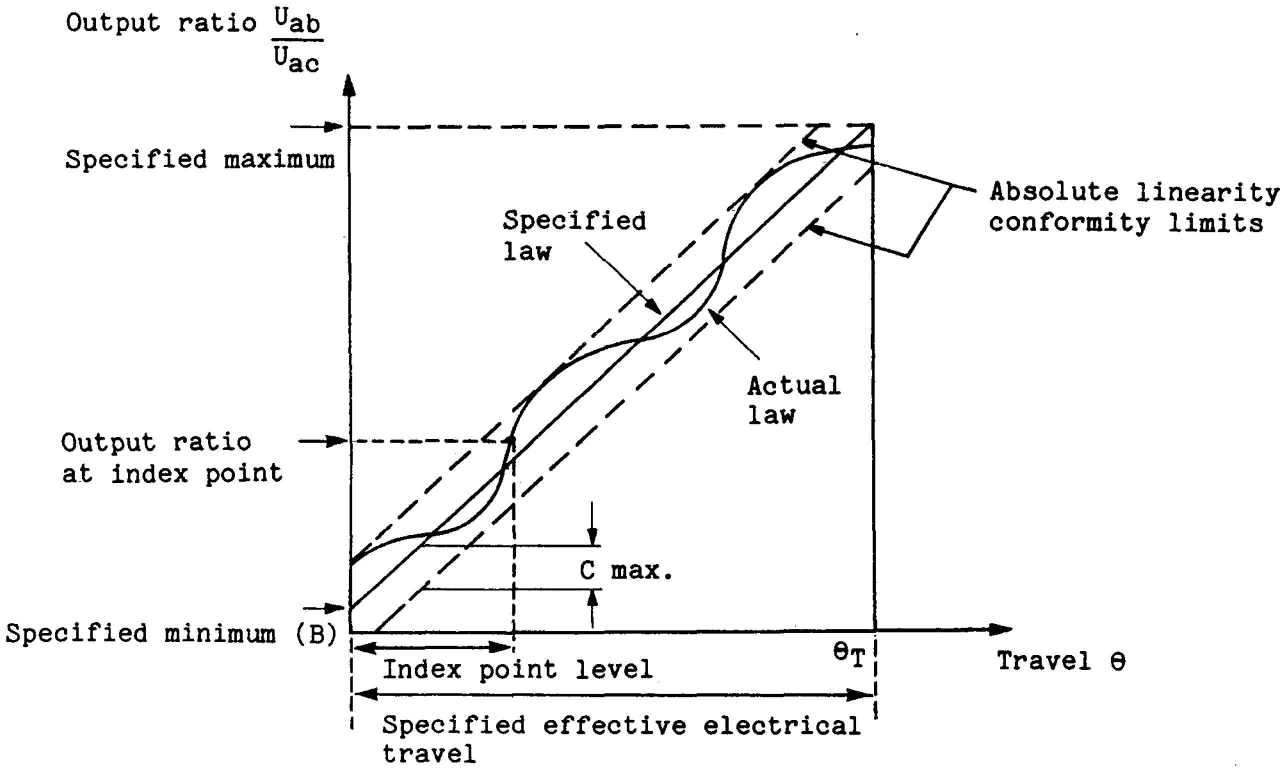

Output ratio $\frac{U_{ab}}{U_{ac}}$
Specified maximum
Specified law
Absolute linearity conformity limits
Actual law
Output ratio at index point
C max.
Specified minimum (B)
Index point level
θ_T
Travel θ
Specified effective electrical travel

Fig. 16 - Absolute linearity

2.2.49.15 Terminal based linearity (see Fig.17) (for wirewound potentiometers only)

The specific type of conformity where the maximum vertical deviation, expressed as a percentage of the total applied voltage, of the actual law from a straight reference line drawn through the specified minimum and maximum output ratios which are separated by the effective electrical travel. Unless otherwise specified, minimum and maximum output ratios are respectively, zero and 100% of total applied voltage.

MATHEMATICALLY: $\frac{U_{ab}}{U_{ac}} = A\left(\frac{\theta}{\theta_A}\right) + B \pm C$

where:

A is the given slope; B is the given intercept at $\theta = 0$; θ_A is the amount of effective electrical travel. Unless otherwise specified A = 1 and B = 0.

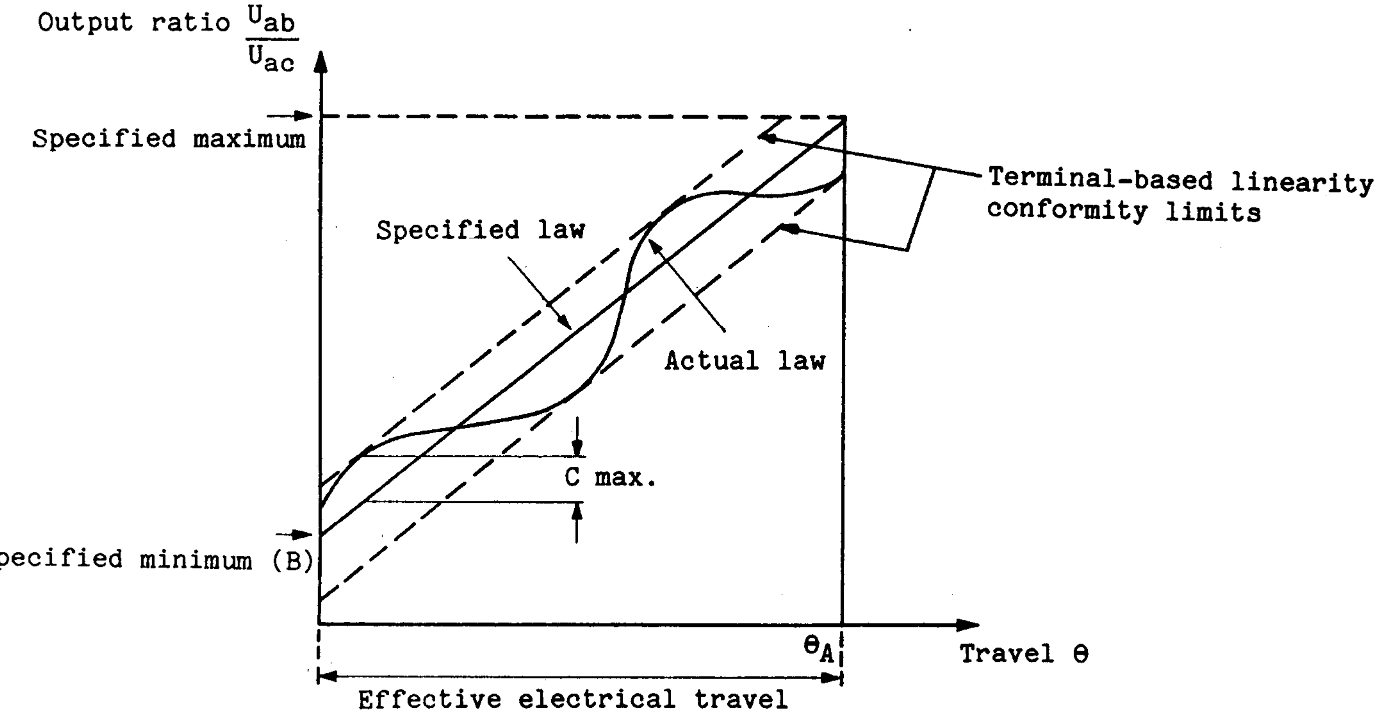

Output ratio $\frac{U_{ab}}{U_{ac}}$
Specified maximum
Terminal-based linearity conformity limits
Specified law
Actual law
C max.
pecified minimum (B)
θ_A
Travel θ
Effective electrical travel

Fig. 17 - Terminal based linearity

2.2.49.16 Index point A

A point of reference fixing the relationship between a specified actuating device position and the output ratio. It is used to establish an actuating device position reference.

2.2.49.17 Tap location

The tap location is the position of a tap relative to some reference.

This is commonly expressed in terms of resistance, output ratio or actuating device position. When an actuating device position is specified, the tap position is the centre of the effective tap width.

2.2.49.18 Effective tap width (see Fig. 18)

The effective tap width is the travel of the actuating device, during which the voltages at the moving contact termination b and the tap connection are essentially the same as the moving contact is moved past the tap in one direction.

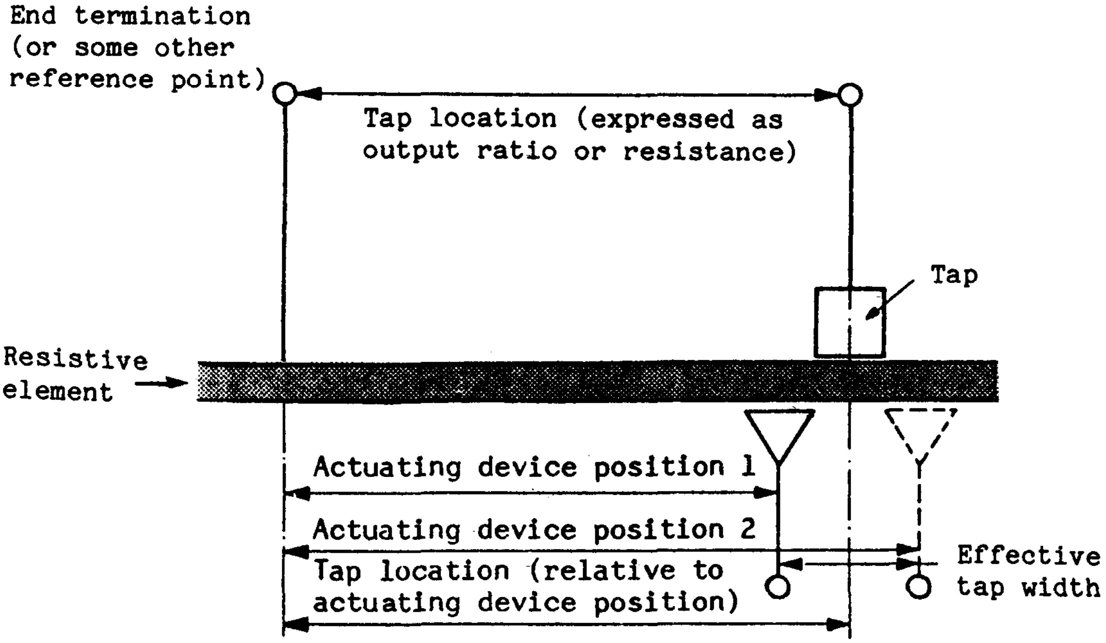

End termination
(or some other
reference point)
Tap location (expressed as
output ratio or resistance)
Tap
Resistive
element
Actuating device position 1
Actuating device position 2
Tap location (relative to
actuating device position)
Effective
tap width

Fig.18 Effective tap width

2.2.49.19 Phasing

The relative alignment of the phasing points of each section of a ganged potentiometer.

2.2.49.20 Phasing point

A point of reference on each section to describe the relative alignment of the sections of a ganged potentiometer with respect to the position of the moving contacts.

2.2.49.21 Rotational noise

Any spurious variation in the electrical output not present in the input, when moving the moving contact and caused by contact resistance variation and/or track resistance variation.

2.2.49.22 Contact resistance variation (C.R.V.)

Change of the resistance between the resistive element and the moving contact when it is moved at a defined speed.

2.2.49.23 Track resistance variation (T.R.V.)

Spurious changes of the output ratio when the moving contact is moved at a defined speed, caused by irregularities of the track.

2.2.49.24 Output smoothness (for non-wirewound types only)

Spurious variation in the electrical output not present in the input. Output smoothness includes effects of contact resistance variations, resolution, and other micro-nonlinearities in the output.

It is expressed as a percentage of the total applied voltage and measured for specified travel increments over the effective electrical travel.

2.2.49.25 Setting ability or resolution (adjustability)

The precision with which the resistance or output voltage ratio of a potentiometer can be set to a desired value.

It is normallly expressed as a percentage of the total resistance.

2.2.49.26 Theoretical resolution

The reciprocal of the number of turns of the resistance winding in the effective electrical travel and is expressed as a percentage. This term is used in the description of wirewound potentiometers and is a measure of sensitivity to which the output ratio of the potentiometer may be set.

2.2.49.27 Simultaneous conformity phasing

The relative alignment of the sections of a ganged potentiometer, from a common reference point, such that the output ratios of all sections fall within their respective conformity limits over the effective electrical travel.

2.2.49.28 Backlash (see Fig.19)

The maximum difference in the actuating device position that occurs when it is moved to the same actual output ratio point from opposite directions.

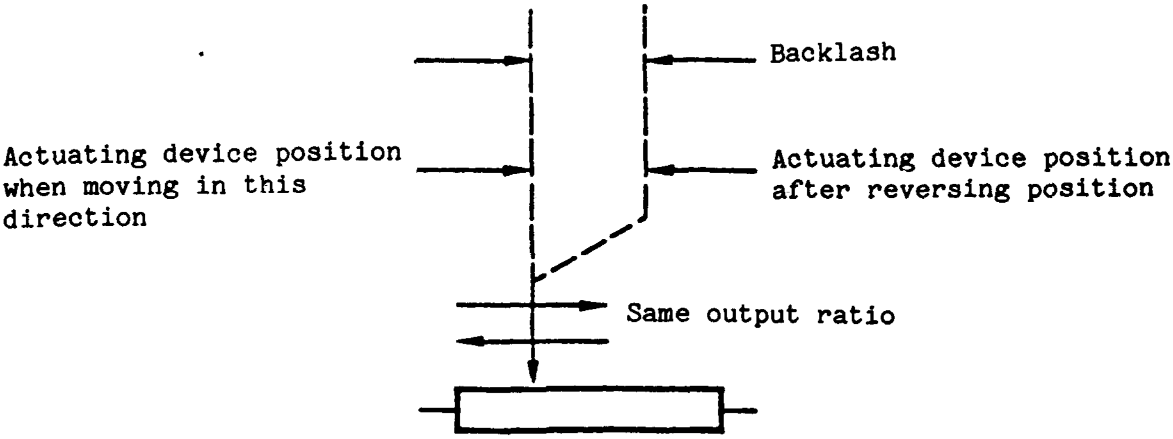

Backlash
Actuating device position when moving in this direction
Actuating device position after reversing position
Same output ratio

Fig. 19 - Backlash

2.2.49.29 Dither

A movement of the control spindle to simulate conditions which may occur in servo systems.

2.3 Preferred values

2.3.1 General

Each sectional specification shall prescribe the preferred values appropriate to the sub-family; for rated resistance see also Sub-clause 2.3.2.

2.3.2 Preferred values of rated resistance

The preferred values of rated resistance shall be taken from the series specified in IEC Publication 63.

2.4 Marking

2.4.1 General

Any marking used on the potentiometers or their packages shall be in conformity with that given in the relevant sectional specification.

2.4.2 Coding

When coding is used for resistance value, tolerance or date of manufacture, the method shall be selected from those given in IEC Publication 62.

SECTION THREE - QUALITY ASSESSMENT PROCEDURES

3. Quality assessment procedures

3.1 Qualification Approval/Quality Assessment Systems

3.1.1 When these documents are being used for the purposes of a full quality assessment system such as the IEC Quality Assessment System for Electronic Components (IECQ), with Qualification Approval and Quality Conformance Inspection, the procedures of Sub-clauses 3.4 and 3.5 shall be complied with.

3.1.2 When these documents are used ouside such quality assessment systems as the IECQ system for purposes such as design proving or type testing, the procedures and requirements of Sub-clauses 3.4.1 and 3.4.2 b) may be used, but the tests and parts of tests shall be applied in the order given in the test schedules.

3.2 Primary Stage of Manufacture

For potentiometer specifications, the primary stage of manufacture is:

For film types:	the deposition of the resistive film on the substrate.
For carbon composition types:	the process which produces the greatest change in polymerisation of the binder.
For wirewound types:	the winding of the resistance wire (or ribbon) on the former.

3.3 Structurally Similar Components

The grouping of structurally similar components for the purpose of qualification approval and quality conformance inspection shall be prescribed in the sectional specification.

3.4 Qualification Approval Procedures

3.4.1 The manufacturer shall comply with:

- the general requirements of the rules of procedure governing qualification approval (IEC Publication QC 001002 (1986), Clause 10).
- the requirements for the primary stage of manufacture contained in Sub-clause 3.2. of this standard.

3.4.2 In addition to the requirements of Sub-clause 3.4.1, the procedure a) or b) below shall apply:

a) The manufacturer shall produce test evidence of conformance to the specification requirements on three inspection lots for lot-by-lot inspection taken in as short a time as possible and one lot for periodic inspection. No major changes in the manufacturing process shall be made in the period during which the inspection lots are taken.

   Samples shall be taken from the lots in accordance with IEC Publication 410 (see Appendix B). The sample shall contain the highest and lowest resistance values represented in the lot and a critical value when this value falls between such high and low values. The highest and lowest resistance values so selected shall define the resistance range for which qualification approval is sought.

   Normal inspection shall be used, but when the sample size would give acceptance on zero defectives, additional specimens shall be taken to meet the sample size required to give acceptance on one defective.

b) The manufacturer shall produce test evidence to show conformance to the specification requirements on the fixed sample size test schedule given in the Sectional Specification.

   The specimens taken to form the sample shall be selected at random from current production or as agreed with the National Supervising Inspectorate.

3.4.3 Qualification Approval obtained as part of a Quality Assessment System shall be maintained by regular demonstration of compliance with the requirements for Quality Conformance (See Sub-clause 3.5). Otherwise this qualification approval must be verified by the rules for the maintenance of qualification approval given in the Rules of Procedure for the IEC Quality Assessment System for Electronic Components (IEC Publication QC 001002 (1986), Sub-clauses 11.5.2 and 11.5.3).

3.5 Quality Conformance Inspection

The blank detail specification(s) associated with a sectional specification shall prescribe the test schedule for Quality Conformance Inspection.

This schedule shall also specify the grouping, sampling and periodicity for lot-by-lot and periodic inspection.

Inspection Levels and AQL's shall be selected from those given in IEC Publication 410.

If required, more than one schedule may be specified.

3.5.1 Certified Records of Released Lots

When certified records of released lots are prescribed in the relevant specification and are requested by a purchaser, the following information shall be given as a minimum:

- attributes information (i.e. number of components tested and number of defective components) for tests in the sub-groups covered by periodic inspection without reference to the parameter for which rejection was made.
- variables information for the change in resistance after the 1 000 h endurance test.

3.5.1.1 Attributes information

When the relevant detail specification requires that attributes information shall be recorded, the following procedures shall be used:

1) When a sub-group comprises a single conditioning test, the total number of rejected potentiometers shall be recorded together with the test in which the failures occurred but without reference to the parameters for which the rejection was made.

2) When a sub-group comprises a number of conditioning tests, the relevant detail specification shall state whether the results shall be recorded for the individual conditioning tests or for a number of them as a group. For the purposes of this specification, the climatic sequence shall be deemed to form a single conditioning test.

3.5.2 Delayed delivery

Potentiometers held for a period exceeding two years (unless otherwise specified in the sectional specification), following the release of the lot shall, before delivery, be re-examined for solderability and resistance as specified in Group A or B Inspection of the detail specification.

The re-examination procedure adopted by the manufacturer's Chief Inspector shall be approved by the National Supervising Inspectorate.

Once a "lot" has been satisfactorily re-inspected, its quality is re-assured for the specified period.

3.5.3 Release for delivery before the completion of Group B tests

When the conditions of IEC 410 for changing to reduced inspection have been satisfied for all Group B tests, the manufacturer is permitted to release components before the completion of such tests.

3.6 Alternative test methods

The test and measurement methods given in the relevant specification are not necessarily the only methods which can be used. However, the manufacturer shall satisfy the National Supervising Inspectorate that any alternative methods which he may use will give results equivalent to those obtained by the methods specified. In case of dispute, for referee and reference purposes the specified methods only shall be used.

3.7 Unchecked parameters

Only those parameters of a component which have been specified in a detail specification and which are were subject to testing can be assumed to be within the specified limits.

It should not be assumed that any parameter not specified will remain unchanged from one component to another. Should for any reason it be necessary for (a) further parameter(s) to be controlled, then a new, more extensive, specification should be used.

The additional test method(s) shall be fully described and appropriate limits, AQL's and inspection levels specified.

SECTION FOUR - TEST AND MEASUREMENT PROCEDURES

4. Test and measurement procedures

4.1 General

The sectional and/or blank detail specifications shall contain tables showing the tests to be made, which measurements are to be made before and after each test or sub-group of tests, and the sequence in which they shall be carried out. The stages of each test shall be carried out in the order written. The measuring conditions shall be the same for initial and final measurements.

If national specifications within any Quality Assessment System include methods other than those specified in the above documents, they shall be fully described.

The issue and amendment status of any IEC Publication 68 test in this section is given in Sub-clause 2.1.

4.2 Standard atmospheric conditions

4.2.1 Standard atmospheric conditions for testing

Unless otherwise specified, all tests and measurements shall be made under standard atmospheric conditions for testing as given in Sub-clause 5.3 of IEC Publication 68-1:

Temperature: 15 °C - 35 °C;
Relative humidity: 45% - 75%;
Air pressure: 86 kPa - 106 kPa (860 mbar - 1 060 mbar).

Before the measurements are made, the potentiometer shall be stored at the measuring temperature for a time sufficient to allow the entire potentiometer to reach this temperature. The same period as is prescribed for recovery at the end of a test is normally sufficient for this purpose.

When measurements are made at a temperature other than the specified temperature, the results shall, when necessary, be corrected to the specified temperature. The ambient temperature during the measurements shall be stated in the test report. In the event of a dispute, the measurements shall be repeated using one of the referee temperatures (as given in Sub-clause 4.2.3) and such other conditions as are prescribed in this specification.

When tests are conducted in a sequence the final measurements of one test may be taken as the initial measurements for the succeeding test.

Note. -During measurements the potentiometer shall not be exposed to draughts, direct sun-rays or other influences likely to cause error.

4.2.2 Recovery conditions

Unless otherwise specified, recovery shall take place under the standard atmospheric conditions for testing (Sub-clause 4.2.1). If recovery has to be made under closely controlled conditions, the standard recovery conditions of Sub-clause 5.4.1 of IEC Publication 68-1 shall be used.

4.2.3 Referee conditions

For referee purpose one of the standard atmospheric conditions for referee tests taken from Sub-clause 5.2 of IEC Publication 68-1, as given below, shall be chosen:

Temperature	Relative humidity	Air pressure
20 ± 1 °C	63 - 67%	86 kPa - 106 kPa (860 mbar - 1 060 mbar)
23 ± 1 °C	48 - 52%	86 kPa - 106 kPa (860 mbar - 1 060 mbar)
25 ± 1 °C	48 - 52%	86 kPa - 106 kPa (860 mbar - 1 060 mbar)
27 ± 1 °C	63 - 67%	86 kPa - 106 kPa (860 mbar - 1 060 mbar)

4.2.4 Reference conditions

For reference purposes the standard atmospheric conditions for reference given in Sub-clause 5.1 of IEC Publication 68-1 apply:

Temperature: 20 °C;
Air pressure: 101.3 kPa (1 013 mbar).

4.3 Drying

When drying is prescribed, the potentiometer shall be conditioned before measurement is made using Procedure I or Procedure II as prescribed in the detail specification.

Procedure I: for 24 ± 4 h in an oven at a temperature of 55 ± 2 °C and at a relative humidity not exceeding 20%.

Procedure II: for 96 ± 4 h in an oven at 100 ± 5 °C.

The potentiometer shall then be allowed to cool in a desiccator using a suitable desiccant, such as activated alumina or silica gel, and shall be kept therein from the time of removal from the oven to the beginning of the specified tests.

4.4 Visual examination and check of dimensions

4.4.1 Visual examination

The condition, workmanship and finish shall be checked by visual examination (See Sub-clause 2.2.20).
There shall be no visual damage.

Marking shall be legible, as checked by visual examination. It shall conform with the requirements of the detail specification.

4.4.2 Dimensions (gauging)

The dimensions indicated in the detail specification as being suitable for gauging shall be checked, and shall comply with the values prescribed in the detail specification.

4.4.3 Dimensions (detail)

All dimensions prescribed in the detail specification shall be checked and shall comply with the values prescribed.

4.4.4 Total mechanical travel (see Fig. 10)

The potentiometer shall be mounted for the measurement of the angular position of the actuating device.

The actuating device shall then be set so that the moving contact is at the extreme anti-clockwise end of the total mechanical travel and the angular position (A) shall be recorded.

The actuating device shall then be set so that the moving contact is at the extreme clockwise end of the total mechanical travel and the angular position (F) shall be recorded.

The total mechanical travel is given by: position F - position A.

The value calculated shall be within the limits given in the detail specification.

4.4.5 Total electrical travel (see Fig. 10)

While mounted for measurement of angular position a voltage not exceeding that given in Sub-clause 4.6.1 shall be applied to terminals a and c.

The actuating device shall be set at the approximate centre of the total mechanical travel and the electrical continuity monitored as the actuating device is turned slowly anti-clockwise until there is an interruption in contact between the moving contact and the resistance element. The angular position (B) of that interruption shall then be recorded. If no interruption occurs, record the position of the end of the mechanical travel.

The actuating device shall then be set at the approximate center of the total mechanical travel and the electrical continuity monitored as the actuating device is turned slowly clockwise until there is an interruption in contact between the moving contact and the resistance element. The angular position (E) of that interruption shall then be recorded. If no interruption occurs, record the position of the end of the mechanical travel.

The total electrical travel is given by: position E - position B.

The value calculated shall be within the limits given in the detail specification.

4.4.6 Effective electrical travel (see Fig. 10)

While mounted for measurement of angular position a voltage not exceeding that given in Sub-clause 4.6.1 shall be applied to terminals a and c.

The actuating device shall then be set at the approximate center of the total electrical travel and then slowly turned anti-clockwise until the output ratio $\frac{U_{ab}}{U_{ac}}$ is within 5% of the value stated in the detail specification for the minimum effective resistance when expressed as a percentage of the total resistance. The angular position (C) shall then be recorded.

The actuating device shall then be set at the approximate centre of the total electrical travel and then slowly turned clockwise until the output-ratio $\frac{U_{bc}}{U_{ac}}$ is within 5% of the value stated in the detail specification for the minimum effective resistance when expressed as a percentage of the total resistance. The angular position (D) shall then be recorded.

Note. -If a greater accuracy is required, the 5% tolerance on the output ratio may be reduced as stated in the detail specification.

The angle of effective electrical travel is given by:
position D - position C.

The value calculated shall be within the limits given in the detail specification.

The angle of ineffective travel (anti-clockwise) is the amount of travel between position A and position C.

The angle of ineffective travel (clockwise) is the amount of travel between position F and position D.

The values calculated shall be less than those given in the detail specification.

4.5 Continuity (except for continuously rotating potentiometers)

4.5.1 The potentiometer shall be loaded in such a way that none of its ratings is exceeded throughout the measurement. The resistance variation between terminations a and b is observed whilst the spindle or lead-screw is operated steadily in each direction at a rate of 2 to 5 cycles (See Sub-clause 2.2.38) per minute.

The resistance variation between terminations a and b shall be reasonably smooth and unidirectional when the spindle is rotated slowly (or the moving contact of a lead-screw actuated device is traversed slowly).

Unless otherwise specified there shall be no electrical discontinuity when the moving contact is moved over the total electrical travel.

4.5.2 There shall be no electrical discontinuity when the clutch is acting at each end of the travel of the moving contact of potentiometers fitted with slipping clutches.

4.6 Element resistance

4.6.1 The measurement shall be made with the moving contact having been set at the end of its travel by anti-clockwise rotation of the actuating device (see Note in Sub-clause 4.6.2).

The resistance shall be measured using a direct voltage of small magnitude applied for as short a time as practicable, in order that the temperature of the resistance element shall not rise appreciably during measurement.

In the event of conflicting results, attributable to such test voltages, the voltage specified in the table shall be used for referee purposes.

Rated resistance (R)	Measuring voltage $V^{+0}_{-10\%}$
10 Ω	0.1
10 to 99 Ω	0.3
100 to 999 Ω	1
1 000 to 9 999 Ω	3
10 000 to 99 999 Ω	10
100 000 to 999 999 Ω	25
⩾1 M Ω	50

4.6.2 The accuracy of the measuring equipment shall be such that the error does not exceed 10% of the tolerance.

When the measurement forms part of a test sequence, it shall be possible to measure a change of resistance with an error not exceeding 10% of the maximum change permitted for that test.

Note. -For special types of potentiometer it may be necessary to give further information on the measurement procedure, including the setting of the moving contact, in the sectional or detail specification.

4.6.3 The resistance value, at 20 °C, between terminations a and c shall be equal to the rated resistance, taking account of the tolerance.

4.7 Terminal resistance

4.7.1 The accuracy of the measuring equipment shall be such that the error does not exeed 5% and the voltage applied to the potentiometer shall be so chosen that the limiting moving contact current is not exceeded.

4.7.2 The resistance shall be measured as follows:

4.7.2.1 Between a and b with the actuating device rotated in an anti-clockwise direction until a minimum resistance is obtained.

4.7.2.2 Between c and b with the actuating device rotated in a clockwise direction until a minimum resistance is obtained.

4.7.3 The resistance shall not exceed that given in the detail specification.

4.8 Maximum attenuation

(Alternative (when specified) to terminal resistance).

4.8.1 Measurement is made:

- between a and b, with the control spindle at the anti-clockwise end of the total electrical travel.
- for potentiometers having inverse non-linear laws between b and c, with the actuating device set at the clockwise end of the total electrical travel.

4.8.2 A supply voltage with frequency of 1.0 ± 0.2 kHz shall be applied across the terminations a and c of the potentiometer under test. The r.m.s. voltage shall not exceed the d.c. voltages specified in Sub-clause 4.6.1.

The voltage from a to b (or b to c when appropriate) shall be measured by an instrument having an internal impedance of at least 1 MΩ. The ratio of the applied voltage to this voltage is the attenuation.

4.8.3 The maximum attenuation shall be not less than that given in the detail specification.

4.9 Resistance law (Conformity)

4.9.1 The potentiometer shall be mounted as for the measurement of angular position of the actuating device.

A constant voltage from a stabilized source not exceeding the voltages given in Sub-clause 4.6.1 shall be applied to terminations a and c of the potentiometer.

4.9.2 The voltage between a and b shall be measured with a high impedance voltmeter at a number of positions of the actuating device which are spaced at approximately equidistant intervals throughout the effective electrical travel.

At each position the output ratio $\frac{U_{ab}}{U_{ac}}$ and the mechanical position of the actuating device shall be recorded.

The measuring method shall be such that the error does not exceed 10% of the specified tolerance or as otherwise specified in the detail specification.

4.9.3 The number of test points for both qualification approval and for quality conformance testing shall be stated in the detail specification.

At each test angular position, the output ratio $\frac{U_{ab}}{U_{ac}}$ shall be within conformance limits given in the detail specification.

4.10 Matching of the resistance law (for ganged potentiometers only) (when applicable)

Note. -The same procedure may be applied when more than two potentiometers are ganged together.

4.10.1 A voltage not exceeding the voltage given in Sub-clause 4.6.1 shall be applied to the terminations a and c of both potentiometers of the pair.

The voltage across:

a and b, and c and b for linear law potentiometers,

or

across a and b for non-linear law potentiometers,

measured on one of the potentiometers shall be compared with the corresponding voltage on the other potentiometer at the identical setting of the actuating device.

4.10.2 The relationship between these two voltages shall be within the limits given in the detail specification.

4.11 Switch contact resistance (when appropriate)

4.11.1 General measuring requirements

Measurements may be carried out with d.c. or a.c. In the case of dispute the d.c. measurement shall govern and the voltage shall be connected with that polarity direction giving the highest resistance value.

The contact resistance shall normally be calculated from the potential difference measured between the points intended for connection of the wiring. The contact shall be made before the measuring voltage is applied.

In order to prevent the breakdown of insulating films on the contacts, the e.m.f. of the measuring circuit, when the contacts are open, shall not exceed 20 mV (d.c. or a.c. peak).

In order to prevent undue heating of the contacts, the current flowing shall not exceed 1 A or the value specified by the detail specification. For a.c. measurements the frequency shall be 1.0 ± 0.2 kHz.

The accuracy of the measuring apparatus shall be such that the error does not exceed 10%.

4.11.2 D.C. measuring cycle

One measuring cycle consists of:

- making the contact
- connection of the voltage source
- measurement with current flowing in one direction
- disconnection of the voltage source
- breaking the contact.

(Half the number of test specimens shall have the voltage connected in one sense and the other half in the other sense).

4.11.3 A.C. measuring cycle

One measuring cycle consists of:

- making the contact
- connection of the voltage source
- measurement
- disconnection of the voltage source
- breaking the contact.

4.11.4 Measurement

The contact resistance shall be measured between any two terminations that are to be connected by the contacting device.

Unless otherwise specified there shall be two measuring cycles carried out in immediate succession. The average of the values thus obtained per contact is the contact resistance. The value of one measurement shall not exceed twice that of the other.

4.11.5 The contact resistance shall not exceed the limit specified in the detail specification.

4.12 Voltage proof

4.12.1 Potentiometers which are designed to be mounted directly onto a metal chassis shall be mounted in the normal manner on a metal plate which shall project not less than 6 mm beyond the potentiometer at all points.

Other designs of potentiometer, e.g. those for mounting on printed boards, shall be mounted as specified in the detail specification.

4.12.2 An alternating voltage of a frequency of 40 Hz to 60 Hz and with a peak value of 1.42 times the isolation voltage shall be applied gradually at a rate of approximately 100 V/s until the proof voltage is obtained. At the discretion of the manufacturer the voltage may, however, be applied more rapidly. The proof voltage shall then be held for 60 ± 5 s between all potentiometer terminations connected together as one pole and any other external metal parts and the plate connected together as the other pole. In addition, in components with insulated actuating devices, the proof voltage shall be applied between all terminations connected together and the actuating device. During the test, the spindle may be operated.

4.12.3 When the test is performed at low air pressure, the conditions of Sub-clause 4.12.2 shall be met except that the proof voltage shall be that stated in the detail specification appropriate to the air pressure.

4.12.4 An alternating voltage of a frequency of 40 Hz to 60 Hz with a value of 900 V r.m.s. for switches for supply mains $\leqslant$ 120 V, and 2 U_R + 1 000 V r.m.s. for switches for supply mains $>$ 120 V, shall be applied gradually at a rate of approximately 100 V/s until the proof voltage is obtained. At the discretion of the manufacturer the voltage may be applied more rapidly. The proof voltage shall then be held for 60 ± 5 s between all switch terminations connected together as one pole and the spindle, metal parts of the case and plate connected together as the other pole.

Note. -U_R is the rated voltage of the switch.

4.12.5 The potentiometer and the switch, when fitted, shall withstand this test without breakdown or flashover.

4.13 Insulation resistance

4.13.1 When mounted as in Sub-clause 4.12.1 above, the insulation resistance shall be measured between:

1) all potentiometer terminations, connected together, and any other external metal parts together with the actuating device (in components with insulated actuating devices);

2) all switch contacts, connected together, and any other external metal parts;

3) open switch contacts.

4.13.2 The insulation resistance shall be measured with a direct voltage of either 100 ± 15 V for potentiometers with an isolation voltage $<$ 500 V or 500 ± 50 V for potentiometers with an isolation voltage $\geqslant$ 500 V.

The voltage shall be applied for one minute or for such shorter time as necessary to obtain a stable reading, the insulation resistance being read at the end of that period.

4.13.3 The value of the insulation resistance shall be not less than that specified in the relevant specification.

4.14 Variation of resistance with temperature

4.14.1 The potentiometer shall be dried using either Procedure I or Procedure II of Sub-clause 4.3 as called for in the detail specification.

4.14.2 Unless otherwise specified in the detail specification, the potentiometer shall be maintained at each of the following ambient temperatures in turn:

a) $20 \begin{smallmatrix} +5 \\ -1 \end{smallmatrix}$ °C

b) lower category temperature ± 3 °C

c) $20 \begin{smallmatrix} +5 \\ -1 \end{smallmatrix}$ °C

d) 70 ± 2 °C

e) upper category temperature ± 2 °C

f) 70 ± 2 °C

g) $20 \begin{smallmatrix} +5 \\ -1 \end{smallmatrix}$ °C

The temperature listed at d) and f) are only applicable to potentiometers having an upper category temperature of 125 °C or higher.

4.14.3 Resistance measurements shall be made at each of the temperatures specified in Sub-clause 4.14.2 after the potentiometer has reached thermal stability.

The condition of thermal stability is judged to be reached when two readings of resistance taken at an interval of not less than 5 min do not differ by an amount greater than that which can be attributed to the measuring apparatus.

The temperature of the chamber at the time of resistance measurement shall be recorded. The error in the measurement of the temperature shall not exceed 1°C.

4.14.4 The temperature characteristics of resistance between 20 °C and each of the other temperatures specified in Sub-clause 4.14.2 shall be calculated from the following formula:

$$\text{Temperature characteristic of resistance} = \frac{\Delta R}{R}$$

where, if the resistances recorded in Sub-clause 4.14.3 are designated R_a, R_b, R_c, R_d, R_e, R_f and R_g respectively, the values of R and ΔR are given are given in the table below:

	Lower category temperature	Upper category temperature	20 °C to 70 °C
R	$\frac{R_a + R_c}{2}$	$\frac{R_c + R_g}{2}$	$\frac{R_c + R_g}{2}$
ΔR	$R_b - R$	$R_e - R$	$\frac{R_d + R_f}{2} - R$

4.15 Rotational noise

For measurement of rotational noise of potentiometers one of the following methods shall be used:

Method A: in cases when the current through the moving contact (I_b) is very low compared to the current passing through the resistive element.

Method B: in all other cases.

The relevant specification shall state, depending on the type of potentiometer concerned, which method shall be used.

4.15.1 Method A

a) A direct voltage of 20 V, with a source resistance of 1 000 ohms, shall be applied to the end terminations a and c of the potentiometer. The moving contact shall be operated through the angle of total mechanical rotation, excluding the switch, in one direction and back at 2 to 5 complete cycles per minute.

b) After three initial cycles the noise output between terminations a and b (or between b and c when appropriate) shall not exceed that specified in the detail specification.

The noise output shall be measured on a test set such as is described in Appendix C.

4.15.2 Method B

A test circuit with the following block diagram shall be used:

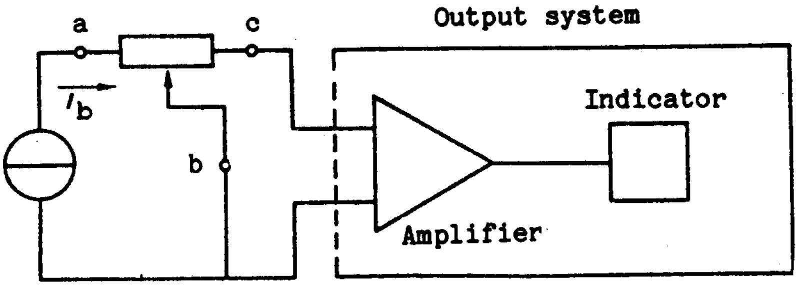


Fig. 20

4.15.2.1 Test circuit conditions

Current I_b

A constant current I_b shall be supplied to the potentiometer terminations a and b. The value of the current shall, on the basis of the rated resistance (R) of the potentiometer, be selected from the following table:

R		I_b
$\geqslant$ 2.2 MΩ		0.01 mA
$\geqslant$ 100 kΩ	< 2.2 MΩ	0.05 mA
$\geqslant$ 10 kΩ	< 100 kΩ	0.1 mA
$\geqslant$ 1 kΩ	< 10 kΩ	1 mA
$\geqslant$ 100 Ω	< 1 kΩ	10 mA
	< 100 Ω	50 mA

The values of I_b specified in the above table are applicable, provided the limiting current for the moving contact is not exceeded and the dissipation power through the resistive element does not exceed the rated power.

Bandwidth of the output system

The bandwidth at 3 dB for wirewound and non-wirewound potentiometers shall be:

for resistance values $\leqslant$ 47 kΩ: 90 Hz - 50 kHz
for resistance values > 47 kΩ: 50 Hz - 5 kHz

The attenuation shall be 6 dB per octave outside the bandwidth.

Input impedance of the "output system"

If the input impedance is considered to be equivalent to a resistance R_{eq} with a capacitance C_{eq} in parallel, it is required that:

$$R_{eq} \geqslant 10\ R$$

$$C_{eq} \leqslant 33\ \mathrm{pF}$$

Output capacitance of the current source including wiring capacitance (C_s)

The output capacitance of the current source including the capacitance of the connecting wires between the source and the potentiometer under test shall not exceed 33 pF.

4.15.2.2 Test conditions

Unless otherwise specified in the detail specification, the moving contact shall be operated for a total of 6 cycles, the speed of operation being 2 to 5 cycles per minute.

For multiturn potentiometers or lead-screw actuated potentiometers this speed shall be limited to a maximum of 3 turns of the shaft per second.

The measurement of the contact resistance variation shall be made during the execution of the last 3 cycles.

Note. -A cycle is one traverse of the resistance element in both directions through 90% of the effective resistance.

4.15.2.3 Contact resistance variation patterns (C.R.V.)

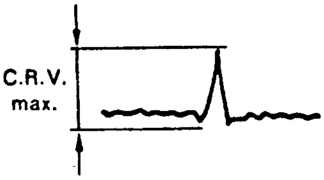


Fig. 21

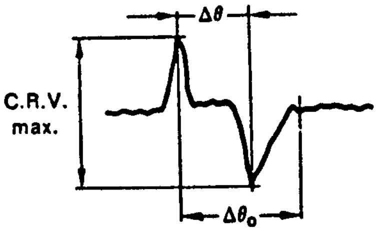


Fig. 22

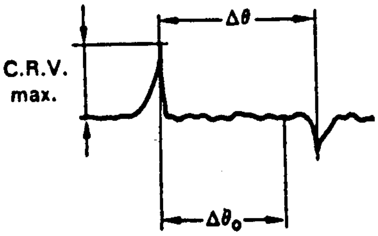


Fig. 23

The above three figures represent typical C.R.V. patterns. The value θ corresponding to the position of the moving contact is plotted in X and the value of the contact resistance at point θ is plotted in Y.

The travel increment $\Delta\theta_0$ is defined as any part of the rated total mechanical travel used for the measurement of contact resistance variation in order to distinguish Fig.22 from Fig.23.

$\Delta\theta < \theta_0$ .... Figure 22
$\Delta\theta \geqslant \theta_0$ .... Figure 23

Unless otherwise specified in the detail specification, the value of the travel increment, $\Delta\theta_0$, shall be zero and Figure 23 shall apply.

Note. -C.R.V. shall be expressed in percentage of the rated resistance of the potentiometer under test.

$\Delta\theta_0$ shall be expressed as a percentage of the rated total mechanical travel.

4.15.2.4 The rotational noise measured between the terminations a and b (or between b and c when appropriate) shall not exceed the limits specified in the detail specification.

4.16 Contact resistance at low-voltage levels

4.16.1 The moving contact shall be set between 40% and 60% of the effective electrical travel and locked in this position so that during subsequent humidity and endurance tests it cannot be moved.

4.16.2 An adjustable d.c. current source, which has an open circuit voltage of 20 ± 2 mV, is connected through an amperemeter to the terminations a and b of the potentiometer as shown in the test circuit in Figure 24. A voltmeter with a high input impedance ($\gg R_N$ of the potentiometer under test) is connected between terminations c and b.

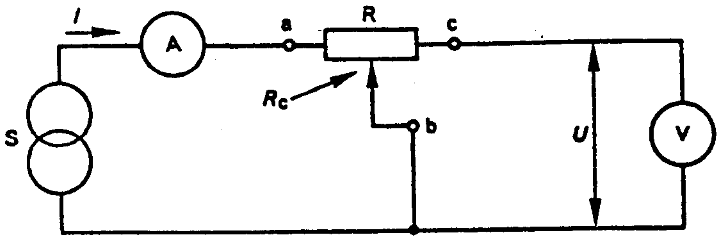


Fig. 24

S = adjustable d.c. source
A = amperemeter
R = potentiometer under test
V = voltmeter

4.16.3 The contact resistance R_c is calculated by dividing the measured voltage U by the applied current I.

Notes 1. -Due to thermal e.m.f.'s in the test specimen, inaccurate results may be found when very low voltages ($U < 3$ mV) are measured. If this is the case, the measurement is repeated with reversed polarity of the current source. The current is adjusted to the same value in both cases and the contact resistance is then the arithmetic mean of the absolute values of the measured voltage divided by the absolute value of the applied current.

2. -An a.c. voltage of 20 mV peak may also be used instead of the d.c. source, provided that it does not influence the test result (e.g. through auto-transformer action in wire-wound potentiometers). In case of dispute the d.c. voltage method shall be used.

4.16.4 When the detail specification for pre-set potentiometers calls for the measurement of contact resistance at low voltage levels, this measurement is made as part of the following tests:

4.40 Damp heat, steady state.

4.43.2 Endurance, electrical (at 70 °C): to be applied for that half of the specimens loaded between terminations a and c.

4.43.3 Endurance, electrical (at upper category temperature): to be applied for that half of the specimens loaded between terminations a and c.

For the above tests an initial contact resistance measurement is made before the tests and final measurements afterwards; all of these measurements with the moving contact in the same position are made according to Sub-clause 4.16.1.

The requirements shall be prescribed in the sectional or detail specification as a maximum resistance variation generally expressed in a percentage of the nominal resistance of the potentiometers.

4.17 Setting ability (adjustability)

This method verifies at three points of the electrical travel the setting ability properties of the potentiometer.

For wirewound potentiometers the influence of the resolution shall be taken into consideration when limits for setting ability are fixed.

Two test methods are described, one for potentiometers used as voltage dividers and the other for potentiometers used as variable resistors.

4.17.1 Method 1: Potentiometer used as a voltage divider

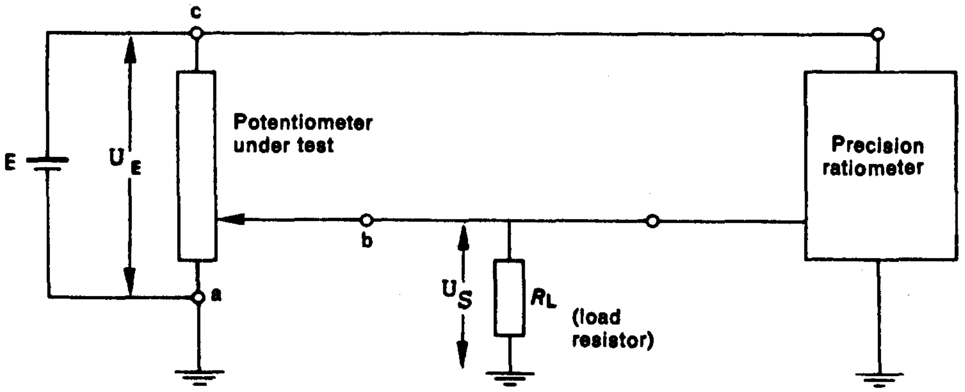


Fig. 25

U_E = 0.1 times the rated voltage or 10 volts (whichever is the smaller)
R_L = 10 R_N, where R_N is the rated resistance value of the test potentiometer.

The precision ratiometer should have an input impedance of at least 10 MΩ. If a digital or electronic type ratiometer with sufficient accuracy is not available, a precision potentiometer standard in combination with a zero detector may be used.

4.17.1.1 Measuring conditions

Adjustment means

Three possibilities for means of adjustment exist:

a) potentiometers with shaft: for adjustment a knob shall be mounted on the shaft with a diameter between 0.8 and 1.2 times the outside body diameter of the potentiometer unless otherwise specified in the detail specification.

b) potentiometers supplied with a specific knob: this knob shall be used.

c) preset potentiometers with screw-driver adjustment: the diameter of the screw-driver handle shall be 8 ± 1 mm.

Accuracy

The accuracy of the measuring equipment shall be such that the error does not exceed 10% of the requirement.

Setting time

The setting of the potentiometer to specified values has to be completed within a specified time.

4.17.1.2 Measurement

The voltage U_E and the resistance R_L shall be set as specified in Figure 25.

The moving contact of the potentiometer shall be adjusted so, that an output voltage near 0.3 U_E is obtained, but outside the limit specified in the relevant specification.
The test operator shall then begin timing and attempt to adjust the potentiometer under test so that $\frac{U_S}{U_E}$ is as close to 0.3 as possible, or within the specified limits.

The adjustment shall be completed within 20 s and is judged to be completed when the operator no longer touches the actuating device.

After completion the value of setting ability shall be calculated from the following formula:

$$\text{setting ability} = \frac{U_{SO}}{U_E} - \frac{U_S}{U_E}$$

where:

$\frac{U_{SO}}{U_E}$ = the desired ratio (in this case 0.3)

$\frac{U_S}{U_E}$ = the ratio measured by the ratiometer

This test procedure shall be repeated at 0.5 U_E and 0.7 U_E.

For non-linear potentiometers, the detail specification shall prescribe the setting points and the index point.

4.17.2 Method 2: Potentiometer used as a variable resistor

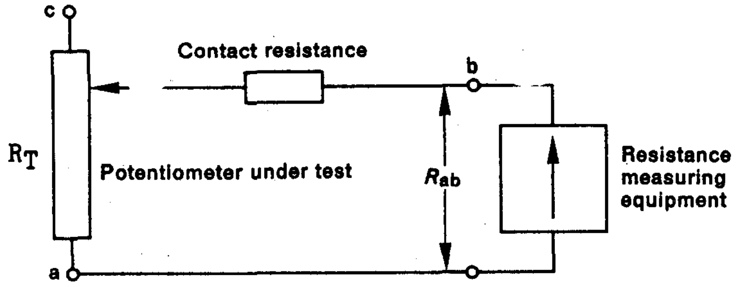


Fig. 26

4.17.2.1 Measuring conditions

The same measuring conditions as for Method 1 apply (see Sub-clause 4.17.1.1).

4.17.2.2 Measurement

The moving contact shall be set to obtain a resistance value R_{ab} near 0.3 R_T, but outside the limit specified in the relevant specification. The test operator shall then begin timing and attempt to adjust the potentiometer under test so that R_{ab} is as close to 0.3 R_T (0.3 R_N may be used) as possible, or within the specified limit.

The adjustment shall be completed within 20 s and is judged to be completed when the operator no longer touches the actuating device.

After completion the value of setting ability shall be calculated from the following formula:

$$\text{setting ability} = \frac{R_{ab} - (R_{ab})_0}{R_T}$$

where:

R_T = the total resistance of the potentiometer under test.

$(R_{ab})_0$ = the desired resistance (in this case 0.3 R_T).

R_{ab} = the resistance value obtained when the adjustment is completed.

This test procedure shall be repeated at 0.5 R_T and 0.7 R_T (or R_N).

Note. -For referee purposes this procedure shall be conducted with suitable equipment so that the current through the contact during adjustment is set at the values specified below:

Resistance value of test potentiometer	Moving contact current
R_T	I_L * (± 20%)
$R_T < 50\,\Omega$	30 mA
50 Ω to 499 Ω	10 mA
500 Ω to 99 kΩ	1 mA
100 kΩ to 2 MΩ	100 µA
$R_T > 2\,M\Omega$	50 µA

* Provided it does not exceed the limiting moving contact current.

4.17.3 Requirements

The potentiometer shall meet the requirements as prescribed in the detail specification.

4.18 Starting torque

When set at a random position away from end stops, or slipping clutch if fitted, the torque necessary to operate the moving contact in either direction shall be as specified in the detail specification.

Note. -When requirements for running torque uniformity exist, they shall be as specified in the detail specification.

4.19 Switch torque

The torque necessary to operate the switch shall not exceed that value specified in the detail specification but it shall be at least twice the starting torque as measured in Sub-clause 4.18.

4.20 End stop torque

4.20.1 There shall be no deformation or other apparent damage when the moving contact is set against each end stop in turn and a torque as specified below is applied to the control spindle for 10 s.

Spindle diameter		Torque	
mm	in	mN.m	ozf. in
> 5.5 ⩽ 5.5	> 0.216 ⩽ 0.216	800 350	112 49

Notes 1. -For potentiometers having a body diameter, or width, equal to or less than 14.5 mm (0.57 inches), the requirements shall be specified in the detail specification.

2. -When the moving contact or actuating device has been designed for special application, the value of the applied torque shall be specified in the detail specification.

4.20.2 When the potentiometer is fitted with a slipping clutch, the moving contact shall be adjusted to each extreme limit of the mechanical travel and a torque shall be applied to the actuating device to force the moving contact to idle for five complete mechanical turns of the actuating device.
During the rotation of the lead-screw a suitable electrical indication device shall be connected between termination b and the termination electrically adjacent to the moving contact.

There shall be no discontinuity. After the test, the moving contact shall be capable of operating in its normal manner. The torque required to slip the clutch shall not exceed 5 times the maximum specified starting torque.

4.21 Locking torque

4.21.1 Potentiometers fitted with locking devices shall be mounted on a metal panel by the normal means of mounting and the spindle shall be set on 40% to 60% of its total mechanical travel. The locking device shall be tightened using the torque figure prescribed below and the value of the output ratio $\frac{U_{ab}}{U_{ac}}$ shall be measured.

Spindle diameter		Torque applied for locking	
mm	in	mN.m	ozf. in
> 5.5 ⩽ 5.5	> 0.216 ⩽ 0.216	1100 - 1200 900 - 1000	155 - 170 127 - 140

4.21.2 The torque of the value prescribed below shall be applied to the spindle of the potentiometer and the value of $\frac{U_{ab}}{U_{ac}}$ shall be measured while the torque is applied to the spindle and shall be compared with the value measured before the torque was applied.

Spindle diameter		Torque applied to the spindle	
mm	in	mN.m	ozf. in
> 5.5 ⩽ 5.5	> 0.216 ⩽ 0.216	200 - 220 130 - 150	28 - 31 18 - 21

The change in the value $\frac{U_{ab}}{U_{ac}}$ shall not exceed the limit prescribed in the sectional or detail specification.

The locking torque shall be removed and the bushing and threads of the potentiometer examined. There shall be no visible damage.

Note. -For potentiometers having a body diameter, or width, equal to or less than 14.5 mm (0.57 inches), the requirements shall be specified in the detail specification.

4.22 Thrust and pull on spindle

4.22.1 The potentiometer shall be rigidly mounted by its normal means.

4.22.2 A thrust followed, when applicable, by a pull, as specified below shall be applied to the control spindle in the direction along its axis. The continuity shall be checked under these conditions.

In both cases the requirements for continuity as specified in Sub-clause 4.5 shall be fulfilled.

Spindle diameter		Thrust/pull	
mm	in	N	lbf
> 5.5 ⩽ 5.5	> 0.216 ⩽ 0.216	25 10	5.5 2.2

4.22.3 The moving contact shall be set at between 40% and 60% of the total mechanical travel and held in such a way as to prevent rotation.
A voltage not exceeding the voltage given in Sub-clause 4.6 shall be applied to terminations a and c of the potentiometer and the voltage between terminations a and b shall be measured with a high impedance voltmeter. The output ratio $\frac{U_{ab}}{U_{ac}}$ shall then be calculated.

A thrust with the value given in the table of Sub-clause 4.22.2 shall be applied to the control spindle in the direction along its axis and under these conditions the voltage between terminations a and b shall be measured and the output ratio $\frac{U_{ab}}{U_{ac}}$ shall again be calculated. The test shall be repeated with a pull with the value given in the table of Sub-clause 4.22.2 in the direction along the axis of the control spindle and, under these conditions the voltage between terminations a and b shall be measured and the output ratio $\frac{U_{ab}}{U_{ac}}$ shall again be calculated.
The change in output ratio with respect to that measured before the thrust was applied shall not exceed that prescribed in the relevant specification.

For precision potentiometers the total axial excursion of the spindle measured at the end of the spindle during the test in Sub-clause 4.22.2 shall not exceed that specified in the detail specification.

4.22.4 The thrust specified below shall be applied to the control spindle in the direction along its axis for 10 s followed by a pull along the direction of the axis of the control spindle for 20 s. There shall be no visible damage.

Spindle diameter		Thrust/pull	
mm	in	N	lbf
> 5.5 $\leqslant 5.5$	> 0.216 $\leqslant 0.216$	125 50	27.5 11

Note. -For potentiometers having a body diameter, or width, equal to or less than 14.5 mm (0.57 in), the conditions of test shall be specified in the detail specification.

4.23 Spindle run-out

The eccentricity of the spindle diameter with respect to the rotational axis of the spindle shall be as specified in the detail specification. It shall be measured at a specified distance from the end of the spindle when the body of the potentiometer is held and the spindle rotated with a specified load applied radially to the spindle.

The potentiometer shall be mounted firmly with the spindle axis in a horizontal position and held rigidly with respect to the dial indicator (see Fig.27). The dial indicator is positioned so that its probe contacts the spindle within 3 mm from the end of the spindle or the edge of any interruption of the smooth cylindrical surface of the spindle.

When the test is specified for spindles with non-cylindrical surfaces such as flats, slots, or splines, a cylindrical shaft-adaptor shall be used.

The probe is depressed sufficiently to ensure a proper positive and negative indication of the dial during rotation of the spindle.

A force of 2.5 N is applied radially to the spindle to remove spindle radial play and is positioned as close to the indicator probe as is practicable. For small diameter spindles, the magnitude of the load applied should be reduced so that it never exceeds that which would cause the spindle to deflect more than one-tenth of the spindle run-out limit. The spindle is then rotated slowly through 360° or through its total mechanical travel, whichever is less. The spindle run-out is the total indicated reading determined by adding the maximum positive and negative readings, without regard to algebraic signs, divided by the length of shaft extensions measured from the mounting surface to the point of measurement, and shall not exceed the value prescribed in the detail specification.

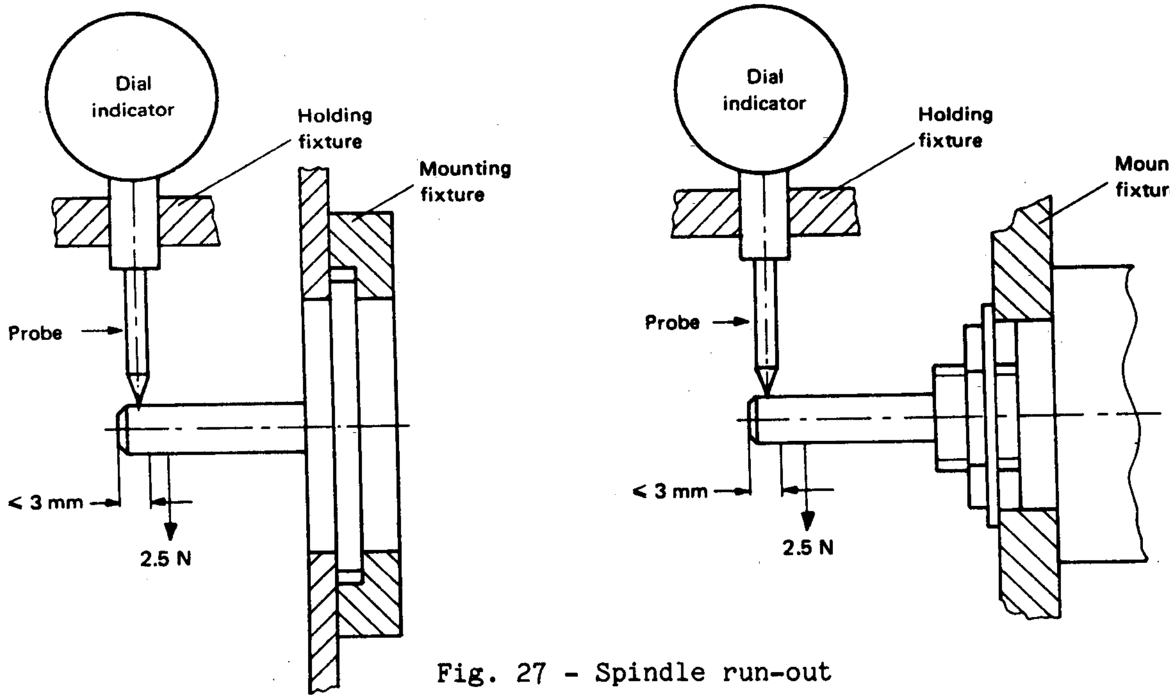


Fig. 27 - Spindle run-out

4.24 Lateral run-out (see Fig.28)

The perpendicularity of the mounting surface of the potentiometer with respect to the rotational axis of the spindle shall be as prescribed in the detail specification. It shall be measured on the mounting surface when the spindle is held and the body of the potentiometer is rotated while specified loads are applied radially and axially to the body of the potentiometer.

The potentiometer shall be mounted firmly in the spindle holding fixture with the spindle in a vertical position (see Fig.28). The spindle shall be clamped within 3 mm of the front surface of the potentiometer without interference and held rigidly with respect to the dial indicator. The potentiometer body shall remain free to rotate. Care shall be taken to ensure that the spindle is not distorted in any way by the mode of clamping or the inherent weight of the potentiometer body.

The dial indicator shall be positioned so that its probe contacts the smooth portion of the mounting surface of the potentiometer less than 3 mm from the outside edge of the mounting surface. A 2.0 N force shall be applied normally to the centre line of the spindle axis, on the potentiometer body within 3 mm of the mounting surface.

Simultaneously a force of 2.5 N shall be applied axially to the centre line of the potentiometer. These loads serve to remove radial play and end play of the spindle. For small diameter spindles, the magnitude of the force applied shall be reduced so that if never exceeds that which would cause the spindle to deflect more than one-tenth of the spindle run-out limit. The probe shall be depressed sufficiently to ensure a proper positive and negative indication during rotation of the potentiometer. The body of the potentiometer shall then be slowly rotated through 360° or through the total mechanical travel, whichever is less. The lateral run-out is the total indicator reading determined by adding the maximum positive and negative readings, without regard to algebraic signs, divided by the mounting surface radius to the point of measurement and shall not exceed the value prescribed in the detail specification.

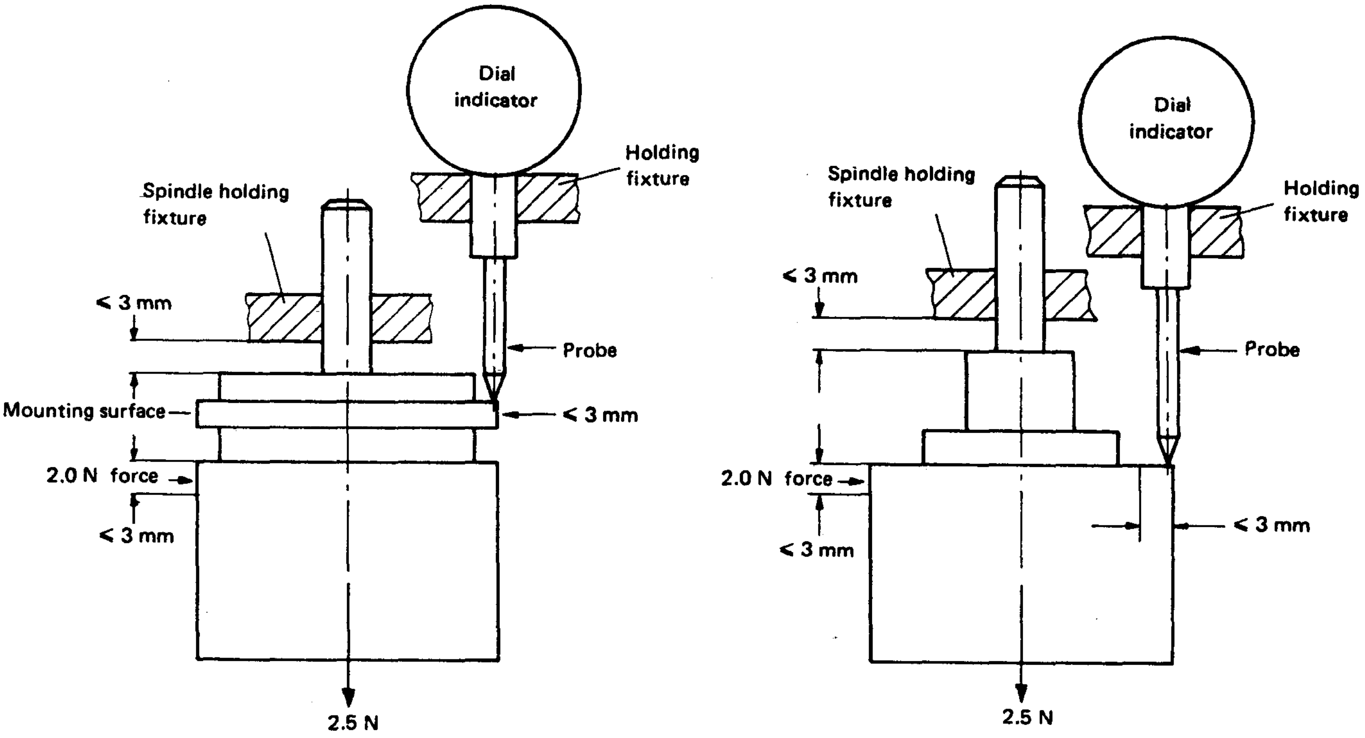


Fig. 28 - Lateral run-out

4.25 Spigot diameter run-out

The eccentricity of the spigot diameter with respect to the rotational axis of the spindle shall be as prescribed in the detail specification. It shall be measured on the spigot diameter when the spindle is held and the body of the potentiometer is rotated while a specified load is applied radially to the body of the potentiometer.

The potentiometer shall be mounted firmly in the spindle holding fixture with the spindle axis in a vertical position (see Fig.29). The spindle shall be clamped within 3 mm of the front surface of the potentiometer without interference and shall be held rigidly with respect to the dial indicator.

The potentiometer body shall remain free to rotate. Care should be taken to ensure that the spindle is not distorted in any way by the mode of clamping or the inherent weight of the potentiometer body. The dial indicator shall be positioned so that its probe contacts the periphery of the spigot surface near the midpoint of the surface. A 2.0 N force shall be applied normally to the centre line of the spindle axis on the potentiometer body within 3 mm of the mounting surface to remove the spindle radial play. For small diameter and/or long spindles the magnitude of the force applied should be reduced so that it never exceeds that which would cause the shaft to deflect more than one-tenth the spindle run-out limit. The probe shall be depressed sufficiently to ensure a proper positive indication of the dial during rotation of the potentiometer.

The body of the potentiometer shall then be slowly rotated through 360° or through the total mechanical travel, whichever is less. The spigot diameter run-out is the total indicated reading determined by adding the maximum positive and negative readings, without regard to algebraic signs, and shall not exceed the value prescribed in the detail specification.

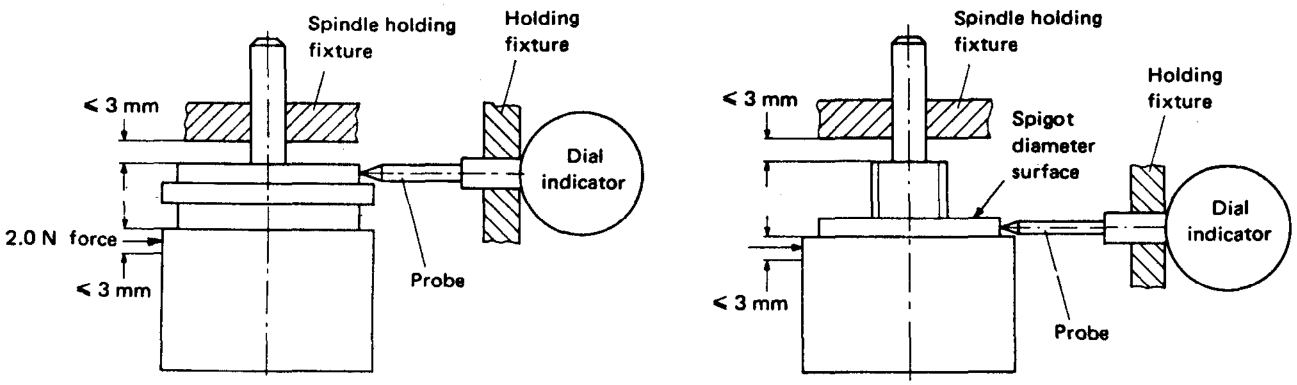


Fig. 29 - Spigot diameter run-out

4.26 Spindle end play

The total axial excursion of the spindle with respect to the potentiometer body, indicated at the end of the spindle with a specified axial load applied alternately in opposite directions shall be as prescribed in the detail specification.

The potentiometer shall be mounted firmly by its normal means with the spindle axis in a vertical position and held rigidly with respect to the dial indicator, leaving the shaft free to rotate (see Fig.30). The dial indicator shall be positioned with its probe parallel (or normal if pivot pointer indicator is used) to the axis of the spindle on the centre line.

The probe shall be depressed sufficiently to ensure a proper positive and negative indication. A 2.0 N force shall be applied alternately in opposite directions along the axis of the spindle.

The spindle end play is the total indicated reading determined by adding the maximum positive and negative readings, without regard to algebraic signs, and shall not exceed the value prescribed in the detail specification.

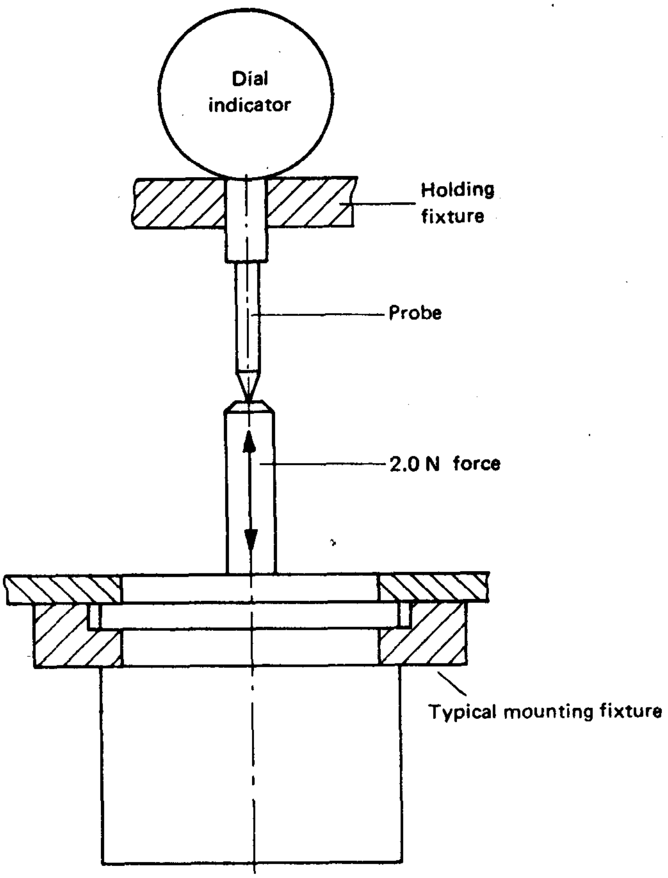


Fig.30 - Spindle end play

4.27 Backlash

4.27.1 The potentiometer shall be mounted for the measurement of the angular position of the actuating device.

A suitable instrument for measuring angular position shall be connected to the control spindle of the potentiometer.
The actuating device shall be positioned at approximately mid-travel, and the potentiometer connected in the circuit of Fig.31.

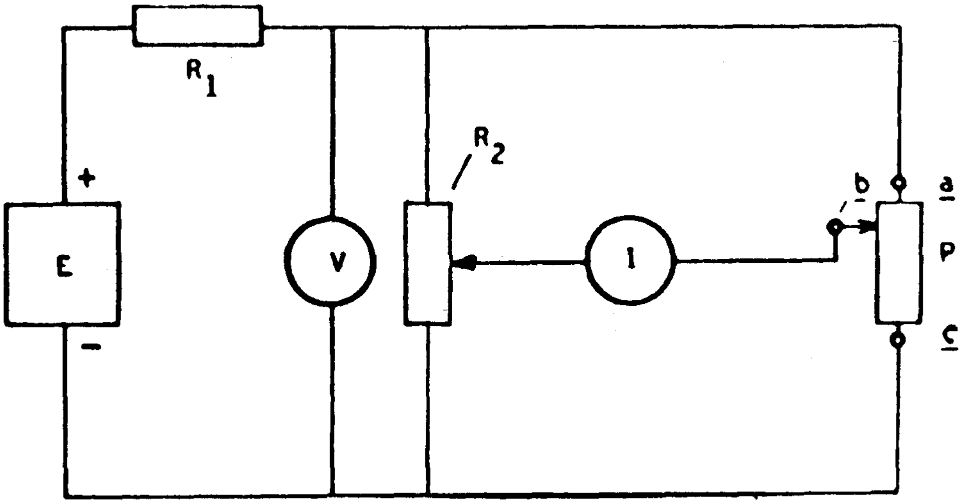


Fig.31 - Test circuit for measurement of backlash

E = d.c. source;

I = zero reading galvanometer;

P = potentiometer under test;

R_1 = resistor limiting the current to a value not exceeding the maximum rated galvanometer current;

R_2 = potentiometer (resistance value shall be of the same order as the potentiometer under test).

Note. -R_2 and P comprise a bridge network.

The actuating device of the potentiometer under test shall be set at approximately mid-travel (but not in a tap or shorted area), and the bridge shall be balanced by means of adjustment of potentiometer R_2.

The actuating device shall then be rotated clockwise by about 10% of the total mechanical travel, followed by an anti-clockwise rotation until the circuit is at balance. The angular position at balance α_1 shall be recorded, after which the rotation shall be continued in an anticlockwise direction by about 10% of the total mechanical travel. The actuating device is then rotated clockwise until the circuit is again at balance. This angular position α_2 shall be recorded.

The backlash is the included angle between the angular positions α_1 and α_2.

Note. -During each rotation, hesitation is permitted, but there shall be no momentary reversal of direction.

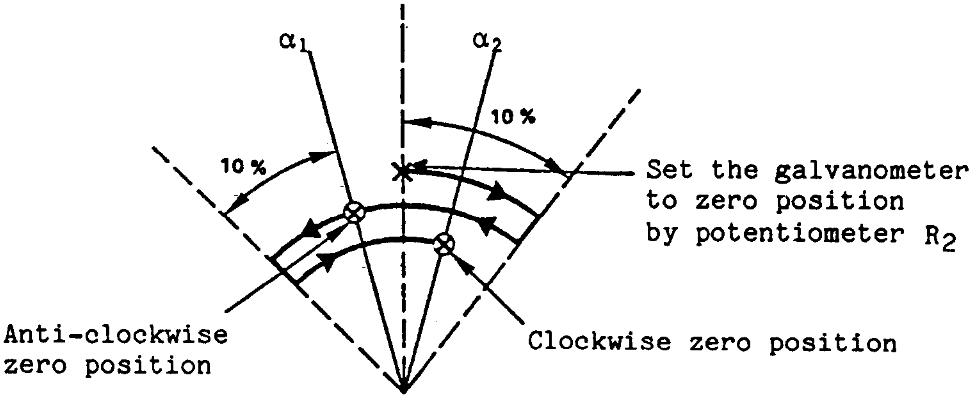

α1
α2
10 %
10 %
Set the galvanometer to zero position by potentiometer R2
Anti-clockwise zero position
Clockwise zero position

Fig. 32 - Measurement of backlash

4.27.2 The backlash expressed in degrees shall not exceed the appropriate value in the table below:

Tolerance on conformity (%)	$(\alpha_1 - \alpha_2)$ in degrees	
	Single turn or continuous rotation	Multiturn
1	0.50	1
0.50	0.25	1
0.25	0.1	1
0.10	0.1	0.4
0.05	0.1	0.1
0.025	0.1	0.1

4.28 Dither

4.28.1 The resistance between terminations a and c shall be measured.

4.28.2.1 The control spindle shall be oscillated at the rate of 55 ± 10 Hz over 5° ± 3° total excursion. The duration of the test shall be related to the number of cycles specified for the mechanical endurance test to the appropriate value in the table below:

Non-wirewound types

Number of cycles	Duration of test (h)
1.25×10^5	0.5
5×10^5	2.0
2.5×10^6	10.0

Wirewound types

(under consideration)

When the number of cycles is greater than 2.5×10^6, the duration of test shall be increased proportionally.

4.28.2.2 When required by the detail specification, the output signal between c and b shall be monitored. The detail specification shall prescribe all necessary requirements.

4.28.3 At the conclusion of this test, the following tests shall be applied:

The potentiometers shall be visually examined. There shall be no visual damage.

The resistance between terminations a and c shall be measured. The change in resistance with respect to the value measured in Subclause 4.28.1 shall not exceed the value prescribed in the relevant specification.

The output smoothness of non-wirewound types shall be measured and shall not exceed the value prescribed in the detail specification.

4.29 Output smoothness

4.29.1 The potentiometer under test shall be connected as shown in Fig. 33.

The output smoothness shall be measured over at least 70% of the effective electrical travel in increments of angle of 1% of the effective electrical travel.

4.29.2 The output smoothness, expressed in % of the voltage U_{ac}, shall not exceed the value given in the detail specification selected from 0.01%, 0.025%, 0.1%, 0.5% and 2.0%

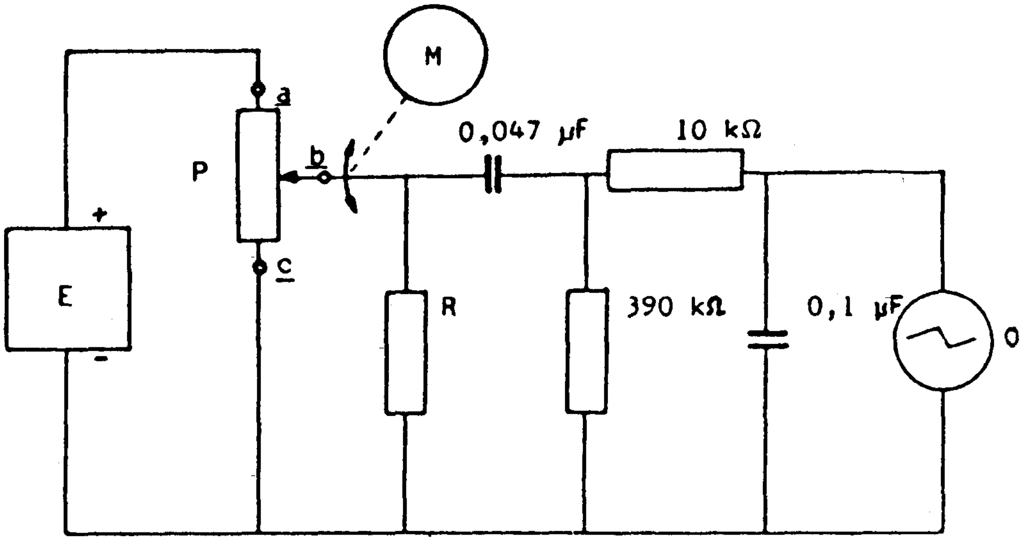


Fig. 33 - Test circuit for measurement of output smoothness

P = potentiometer under test;

E = d.c. source of 10 V or rated voltage (whichever is the less);

R = 100 x rated resistance or as specified in the detail specification;

O = oscilloscope having pass band $\geqslant$ 1 kHz and input impedance $\geqslant$ 1 MΩ;

M = rotates the actuating device through not less than 80% and not greater than 95% of the effective electrical travel in alternate directions. The speed of rotation shall be between 3 and 5 revolutions per minute and shall be constant for at least 70% of the duration.

4.30 Robustness of terminations

The potentiometers shall be subjected to the procedure of tests Ua_1, Ub, or Ud of IEC Publication 68-2-21, as applicable.

Note. -Test Ub shall not be applied if the detail specification describes the terminations as rigid.

4.30.1 The resistance between terminations a and c shall be measured.

4.30.2 Test Ua_1 - Tensile

The force applied for 10 s shall be:

- for terminations other than wire end terminations: 20 N;
- for wire terminations, see table below:

Nominal cross-sectional area (mm^2)	Corresponding nominal diameter for circular section wires (mm)	Force (N)
$S \leqslant 0.05$	$d \leqslant 0.25$	1
$0.05 < S \leqslant 0.1$	$0.25 < d \leqslant 0.35$	2.5
$0.1 < S \leqslant 0.2$	$0.35 < d \leqslant 0.5$	5
$0.2 < S \leqslant 0.5$	$0.5 < d \leqslant 0.8$	10
$0.5 < S \leqslant 1.2$	$0.8 < d \leqslant 1.25$	20
$S > 1.2$	$d > 1.25$	40

4.30.3 Test Ub - Bending (wire terminations)

(see Note of Sub-clause 4.30)

Method 1: Two consecutive bends shall be applied in each direction.

4.30.4 Test Ub - Bending (tag terminations)

(see Note of Sub-clause 4.30)

Method 1: Two consecutive bends shall be applied in each direction.

4.30.5 Test Ub - Bending (printed board terminations)

(see Note of Sub-clause 4.30)

Printed board terminations, which are not described as rigid, shall be subjected to the following bending test. The potentiometers shall be firmly clamped and each termination shall be bent through 90°. The radius of curvature shall be approximately 1 mm. The bending centre shall be 3 ± 0.5 mm from the body of the potentiometer for terminations which are 10 mm or longer. For terminations shorter than 10 mm, the bending centre shall be at a point 1.5 ± 0.5 mm from the mounting plane of the potentiometers. The terminations shall then be returned to the original position and be bent 90° in the opposite direction with the same radius and the same bending point. The termination shall then be returned to the original position. The bends shall be made slowly.

4.30.6 Test Ud - Torque (nuts and threaded terminations)

In accordance with IEC Publication 68-2-21.

4.30.7 Test Ud - Torque (integral fixing devices)

In accordance with IEC Publication 68-2-21.

4.30.8 Final measurements

- After each of these tests, the potentiometers shall be visually examined. There shall be no visible damage.
- The resistance between terminations a and c shall be measured (see Note). The change of resistance with respect to the value measured in Sub-clause 4.30.1 shall not exceed the value prescribed in the relevant specification.

Note. -When several of the tests in this Sub-clause are performed as a sequence, this resistance measurement shall only be made at the end of the sequence.

4.31 Sealing

4.31.1 Static seals (Type A)

Potentiometers fitted with static seals shall be subjected to Test Qa of IEC Publication 68-2-17.

Unless otherwise specified in the detail specification, the seals shall be tested in each direction at a pressure of 100 to 110 kPa.

4.31.2 Operational seals (Type B)

4.31.2.1 Normal test

Potentiometers fitted with operational seals shall be subjected to Test Qa of IEC Publication 68-2-17.

Unless otherwise specified in the detail specification, the seals shall be tested at a pressure of 100 to 110 kPa. The rate of operation shall be 5 cycles per min.

The rate of leakage shall not exceed 1 cm^3/h.

4.31.3 Container sealing

The potentiometers shall be subjected to Method 2 of Test Qc of IEC Publication 68-2-17. Unless otherwise specified in the relevant specification, the temperature shall be 1 °C to 5 °C above the upper category temperature.

There shall be no leakage as determined by repetitive bubbles emerging from the potentiometer.

4.32 Solderability

4.32.1 Potentiometers shall be subjected to test Ta of IEC Publication 68-2-20, either using the solder bath method (Method 1) or the soldering iron method (Method 2) or the solder globule method (Method 3) as prescribed by the detail specification.

4.32.2 When the solder bath method (Method 1) is specified, the following requirements apply:

4.32.2.1 Bath temperature: 235 ± 5 °C

Immersion time: 2.0 ± 0.5 s

Depth of immersion (from the seating plane or component body):

a) All potentiometers except those of b) below:
$2.0 ^{+0}_{-0.5}$ mm, using a thermal insulating screen of 1.5 ± 0.5 mm thickness.

b) Potentiometers indicated by detail specification as being not designed for use on printed boards: $3.5 ^{+0}_{-0.5}$ mm.

4.32.2.2 The terminations shall be examined for poor tinning as evidenced by free flowing of the solder with wetting of the terminations.

4.32.2.3 When the solder bath method is not applicable, the detail specification shall define both the method, test conditions and the requirements.

Note. -When the solder globule method is used, the requirement shall include the soldering time.

4.33 Resistance to soldering heat

4.33.1 When prescribed in the detail specification, the potentiometers shall be dried using either Procedure I or Procedure II of Sub-clause 4.3.

The resistance between terminations a or c shall be measured.

4.33.2 Unless otherwise stated in the relevant specification, the potentiometers shall undergo test Tb of IEC Publication 68-2-20 with the following requirements:

a) All potentiometers except those of b) below:

Method 1A, with a duration of 5 or 10 s, as specified in the detail specification.
Depth of immersion from the seating plane $2^{+0}_{-0.5}$ mm,
using a thermal insulating screen of 1.5 ± 0.5 mm thickness.

b) Potentiometers not designed for use on printed boards as indicated in the detail specification:

Method 1B
Depth of immersion from the component body: $3.5^{+0}_{-0.5}$ mm

4.33.3 The potentiometers shall then remain under the standard atmospheric conditions for recovery for 4 ± 0.5 h unless it can be demonstrated that stability is reached earlier.

The resistance between terminations a and c shall be measured. The change in resistance with respect to the value measured in Sub-clause 4.33.1 shall not exceed the value prescribed in the relevant specification.

The terminal resistance shall be measured as prescribed in Sub-clause 4.7 and shall be less than the limit prescribed in the relevant specification.

4.34 Change of temperature

4.34.1 This test is only applicable to potentiometers having a difference between the upper and lower category temperatures exceeding 95 °C.

4.34.2 The resistance between terminations a and c shall be measured.

4.34.3 For preset potentiometers only, the moving contact shall be set at between 40% and 60% of the total mechanical travel.

A voltage not exceeding the voltage given in Sub-clause 4.6 shall be applied to terminations a and c of the potentiometer and the voltage between terminations a and b shall be measured with a high impedance voltmeter.

The output ratio $\frac{U_{ab}}{U_{ac}}$ shall be calculated.

4.34.4 The potentiometers shall be subjected to Test N of IEC Publication 68-2-14.

The low and high temperatures prescribed in Test N shall be the lower and upper category temperatures respectively and the duration of the exposure at these temperatures shall be 30 min.

Potentiometers having a rated dissipation equal to or less than 10 W shall be subjected to Test Na, those greater than 10 W shall be subjected to Test Nb.

The rate of change of temperatures in Test Nb shall be 5 °C/min.

4.34.5 After recovery the potentiometers shall be visually examined. There shall be no visible damage.

4.34.6 For preset potentiometers only, the output ratio $\frac{U_{ab}}{U_{ac}}$ shall be determined after recovery as given in Sub-clause 4.34.3. The change in output ratio with respect to that measured in Sub-clause 4.34.3 shall not exceed the value prescribed in the detail specification.

4.34.7 The resistance between terminations a and c shall be measured. The change in resistance with respect to the value measured in Sub-clause 4.34.2 shall not exceed the value prescribed in the relevant specification.

4.35 Vibration

4.35.1 The resistance between terminations a and c shall be measured.

4.35.2 For preset potentiometers only, the moving contact shall be set at between 40% and 60% of the total mechanical travel.
A voltage not exceeding the voltage given in Sub-clause 4.6 shall be applied to terminations a and c of the potentiometer and the voltage between terminations a and b shall be measured with a high impedance voltmeter.

The output ratio $\frac{U_{ab}}{U_{ac}}$ shall be calculated.

4.35.3 The potentiometer shall be subjected to Test Fc of IEC Publication 68-2-6 using the appropriate degree of severity. The detail specification shall specify the method of mounting to be used.

4.35.4 Additional requirements during test

4.35.4.1 Potentiometers not fitted with a locking device

The moving contact shall be set between 40% and 60% of the total mechanical travel unless this operation has been performed as part of the requirements of Sub-clause 4.35.2. Effective continuity between the moving contact and the resistance element shall be checked by oscillographic, or other suitable, means and shall be maintained.

4.35.4.2 Potentiometers fitted with locking device

Those potentiometers fitted with an integral locking device shall have the moving contact set and locked at between 40% and 60% of the total mechanical travel, unless this operation has been performed as part of the requirements of Sub-clause 4.35.2.

During the test, any transient resistance changes of the resistance between terminations a and b or, if the resistance between c and b is smaller, between these latter terminations, shall not exceed that specified in the relevant specification.

4.35.5 After the test, the potentiometers shall be visually examined. There shall be no visible damage.

4.35.6 For preset potentiometers, after the test, the output ratio $\frac{U_{ab}}{U_{ac}}$ shall be compared with that measured in Sub-clause 4.35.2 and the change in output ratio shall not exceed that specified in the relevant specification.

4.35.7 The resistance between terminations a and c shall be measured. The change in resistance with respect to the value measured in Sub-clause 4.35.1 shall not exceed the value prescribed in the relevant specification.

4.36 Bump

4.36.1 The resistance between terminations a and c shall be measured.

4.36.2 The potentiometers shall be subjected to Test Eb of IEC Publication 68-2-29 using the appropriate degree of severity.

The relevant specification shall state the degree of severity at which the test shall be performed and the method of mounting to be used.

4.36.3 The potentiometers shall be visually examined. There shall be no visible damage.

The resistance between terminations a and c shall be measured. The change in resistance with respect to the value measured in Sub-clause 4.36.1 shall not exceed the value prescribed in the relevant specification.

4.37 Shock

4.37.1 The resistance between terminations a and c shall be measured.

4.37.2 The potentiometers shall be subjected to test Ea of IEC Publication 68-2-27, using the mounting method and degree of severity laid down in the relevant specification. During the test, the potentiometers shall be monitored for electrical discontinuities, of 100 µs or greater, between the terminals a and b. There shall be no such discontinuities.

4.37.3 The potentiometers shall be visually examined. There shall be no visible damage.

The resistance between terminations a and c shall be measured. The change in resistance with respect to the value measured in Sub-clause 4.37.1 shall not exceed the value prescribed in the relevant specification.

4.38 Climatic sequence

4.38.1 Initial requirements

4.38.1.1 The potentiometers shall be dried using either Procedure I or Procedure II of Sub-clause 4.3 as called for in the relevant specification.

4.38.1.2 The resistance between terminations a and c shall be measured.

4.38.2 Dry heat

4.38.2.1 The potentiometers shall be subjected to the procedure of Test Ba of IEC Publication 68-2-2 using the appropriate degree of severity.

4.38.2.2 After recovery the potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.

4.38.3 Damp heat, cyclic, test Db, first cycle

4.38.3.1 The potentiometers shall be subjected to test Db of IEC Publication 68-2-30 for one cycle of 24 h, using a temperature of 55 °C (Severity b).

4.38.3.2 After recovery, the potentiometers shall be subjected immediately to the cold test.

4.38.4 Cold

4.38.4.1 The potentiometers shall be subjected to the procedure of Test Aa of IEC Publication 68-2-1, for a period of 2 h using the appropriate degree of severity.

4.38.4.2 While still at the specified low temperature and at the end of the period of low temperature, the starting torque shall be measured, except for potentiometers of category -/-/04.

The starting torque shall be measured, as specified in Sub-clause 4.18 after the moving contact has been operated once over the whole resistive element and back, using a torque not exceeding six times the maximum value specified in the detail specification for starting torque but with an upper limit not exceeding that specified for end stop torque in Sub-clause 4.20.

The starting torque of the potentiometer shall not exceed the value specified in the detail specification.

The operating torque of the switch shall be measured as specified in Sub-clause 4.19 and shall not exceed the value prescribed in the detail specification.

4.38.5 Low air pressure

4.38.5.1 The potentiometers of categories 40/-/- and 55/-/- shall be subjected to the procedure of Test M of IEC Publication 68-2-13 using the degree of severity prescribed in the relevant specification.

4.38.5.2 The test shall be carried out between 15 °C and 35 °C and the duration of the test shall be 1 h.

4.38.5.3 While still at the specified low pressure and during the last five minutes of the one hour period a voltage proof test in accordance with Sub-clause 4.12.3 shall be carried out.

The test voltage shall be in accordance with that given in the detail specification.

During and after this test there shall be no sign of breakdown or flashover.

4.38.6 Damp heat, cyclic, test Db, remaining cycles

The potentiometer shall be subjected to test Db, Variant 1, of IEC Publication 68-2-30 for the following cycles of 24 h as indicated in the table below at a temperature of 55°C (severity b):

Categories	Number of cycles
-/-/56	5
-/-/21	1
-/-/10	1
-/-/04	None

4.38.7 D.C. load (when specified in the detail specification)

At the end of the test, the potentiometers shall be subjected to the standard atmospheric conditions for testing. The time of transfer shall be as short as possible and shall not exceed 5 min. At 30 ± 5 min after removal from the chamber for the damp heat cyclic test, the potentiometers shall be subjected to a d.c. voltage for 1 min. The voltage shall be the rated voltage or the limiting element voltage, whichever is the smaller and shall be applied between terminations a and c.

4.38.8 Isolation voltage (to be applied when the d.c. load of Sub-clause 4.38.7 is not specified in the detail specification)

At the end of the conditioning period, the potentiometers shall be removed from the chamber; shaken so as to remove droplets of water and within 15 min the isolation voltage, as specified in the detail specification, shall be applied for one minute between the terminations connected together and the spindle (when metallic) and/or the mounting plate (see Sub-clauses 4.12.1 and 4.12.2).

There shall be no breakdown or flashover.

4.38.9 Recovery

The potentiometers shall then be subjected to the standard atmospheric conditions for recovery for not less than one hour and not more than 2 h.

4.38.10 Final test and measurements

The potentiometers shall then be subjected to such of the following tests and measurements as are prescribed in the detail specification.

After the recovery prescribed in Sub-clause 4.38.9 has been completed, the times for testing shall be:

Sub-clause 4.38.10.1: to be completed during the first hour.

Sub-clause 4.38.10.2 and 4.38.10.3: to be completed in not more than two hours.

Sub-clause 4.38.10.4 to 4.38.10.7: to be completed in not more than six hours.

4.38.10.1 After recovery the potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.

4.38.10.2 The resistance between terminations a and c shall be measured. The change in resistance with respect to the value measured in Sub-clause 4.38.1 shall not exceed the value prescribed in the relevant specification.

4.38.10.3 The insulation resistance shall be measured as specified in Sub-clause 4.13. The value shall not be less than that prescribed in the relevant specification.

4.38.10.4 The switch contact resistance shall be measured as specified in Sub-clause 4.11 and shall not exceed the limit prescribed in the detail specification.

4.38.10.5 The continuity shall be tested as specified in Sub-clause 4.5 and the requirements of the detail specification shall be met.

4.38.10.6 The starting torque shall be measured as specified in Sub-clause 4.18 and shall be within the limits prescribed in the detail specification.

4.38.10.7 The voltage proof test shall be carried out as specified in Sub-clause 4.12. There shall be no breakdown or flashover.

4.39 Damp heat, steady state

4.39.1 The resistance between terminations a and c shall be measured.

4.39.2 The potentiometers shall be subjected to Test Ca of IEC Publication 68-2-3, using the degree of severity corresponding to the climatic category of the potentiometer as indicated in the detail specification.

4.39.2.1 Potentiometers which are designed to be mounted directly onto a metal chassis shall be divided into three groups:

1) The first group shall be subjected to this test without voltage applied.

2) The second group shall be subjected to the test with a direct voltage between terminations a and c. The voltage to be applied shall be selected from the following series:

   0 - 4 - 6.3 - 10 and 16 V.

   The voltage selected shall be the next lower value to that derived from a calculation of 10% of the rated voltage, or 10% of the limiting element voltage, whichever is the smaller.
   Throughout the test period the voltage shall be kept as closely as possible to the specified voltage, a tolerance of ± 5% is allowed for mains voltage fluctuations and similar factors.

3) The third group shall be subjected to the test with a direct voltage of 20 ± 2 V between the mounting plate and one of the end terminations. The mounting plate is connected to the negative pole, the termination to the positive pole of the voltage source. The voltage shall be applied continuously throughout the test.

4.39.2.2 All other potentiometers shall be divided into two groups and only the tests (1) and (2) of Sub-clause 4.39.2.1 shall be carried out.

4.39.3 D.C. load (when specified in the detail specification)

At the end of the test, the potentiometers shall be subjected to the standard atmospheric conditions for testing. The time of transfer shall be as short as possible and shall not exceed 5 min. At 30 ± 5 min after removal from the chamber for the damp heat, steady state test, the potentiometers shall be subjected to a d.c. voltage for 1 min. The voltage shall be the rated voltage or the limiting element voltage, whichever is the smaller and shall be applied between terminations a and c.

4.39.4 Isolation voltage (to be applied when the d.c. load test of Sub-clause 4.39.3 is not specified in the detail specification)

At the end of the conditioning period, the potentiometers shall be removed from the chamber; they shall be shaken so as to remove droplets of water and within 15 min the isolation voltage as specified in the detail specification shall be applied for 1 min between the terminations connected together and the spindle (when metallic) and/or the mounting plate (see Sub-clauses 4.12.1 and 4.12.2).

There shall be no breakdown or flashover.

4.39.5 Recovery

The potentiometers shall then be subjected to the standard atmospheric conditions for recovery for not less than one hour and not more than two hours.

4.39.6 Final tests and meaurements

After the recovery prescribed in Sub-clause 4.39.5 has been completed the times for testing shall be:

Sub-clause 4.39.6.1 to be completed in less than 1 h.

Sub-clause 4.39.6.2 to Sub-clause 4.39.6.3 } to be completed in less than 2 h.

Sub-clause 4.39.6.4 to Sub-clause 4.39.6.8 } to be completed in less than 7 h.

4.39.6.1 The potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.

4.39.6.2 The resistance between terminations a and c shall be measured. The change in resistance with respect to the value measured in Sub-clause 4.39.1 shall not exceed the value prescribed in the relevant specification.

4.39.6.3 The insulation resistance shall be measured as specified in Sub-clause 4.13. The value shall not be less than that prescribed in the relevant specification.

4.39.6.4 The switch contact resistance shall be measured as specified in Sub-clause 4.11 and shall not exceed the limit prescribed in the detail specification.

4.39.6.5 The continuity shall be tested as specified in Sub-clause 4.5 and the requirements of the detail specification shall be met.

4.39.6.6 The starting torque shall be measured as specified in Sub-clause 4.18 and shall be within the limits prescribed in the detail specification.

4.39.6.7 The rotational noise shall be measured as specified in Sub-clause 4.15.2 or in 4.16.2 whichever is applicable, and shall not exceed the limit prescribed in the detail specification.

4.39.6.8 The voltage proof test shall be carried out as specified in Sub-clause 4.12 or as stated in the detail specification. There shall be no breakdown or flashover.

4.40 Mechanical endurance (potentiometers)

4.40.1 The resistance between terminations a and c shall be measured.

4.40.2 Half the specimens shall be loaded between terminations a and c and the other half shall be unloaded. (When a special requirement exists for loading through the moving contact, the detail specification shall specify the conditions to be used).

For potentiometers not exceeding 10 W rated dissipation the use of a d.c. voltage, provided the ripple does not exceed 5%, shall be the preferred method. If, however, it can be demonstrated that there will be no relaxation in the severity of the test, an a.c. voltage may be used. For potentiometers exceeding 10 W rated dissipation an a.c. voltage shall be applied. The applied voltage shall be the rated voltage or the limiting element voltage, whichever is the less.

4.40.3 Unless otherwise specified the potentiometers shall be mounted as specified in Sub-clause 4.43.1.5. The potentiometers shall be subjected to this test in such a manner that the temperature of any one potentiometer shall not appreciably influence the temperature of any other potentiometer. There shall be no undue draught over the potentiometers.

4.40.4 A suitable driving mechanism shall be fixed to the control spindle and arranged to operate cyclically so that the mechanical travel is greater than 90% of the total mechanical travel. The torque shall be not more than 200 mN.m for potentiometers with a rated dissipation not exceeding 10 W and not more than 714 mN.m for potentiometers exceeding 10 W rated dissipation.

4.40.5 Unless otherwise specified in the detail specification, the number of cycles of operation and the rate of operation for single turn rotary potentiometers shall be as given in the table below:

Potentiometer type	Number of cycles of operation	Rate (cycles/min)
Non-wirewound	25 000 or 10 000 as specified in the detail specification	10 to 17
Wirewound	5 000	5 to 10
Preset	500 or 200 as specified in the detail specification	5 to 10

Notes 1. -A cycle of operation is defined as the travel of the moving contact from one end of the resistance element to the other and back. And when a switch is fitted, this includes the operation of the switch.

2. -For other constructions of potentiometers e.g. multi-turn helical, continuous rotation, lead-screw actuated, etc. the detail specification shall specify the number of operations and the rate of operation. It shall also define the cycle of operation.

4.40.6 After the test the potentiometers shall be allowed to remain under standard atmospheric conditions for test for 1 to 2 h. After this period such of the following tests, prescribed in the detail specification, shall be made.

1) The potentiometer shall be visually examined. There shall be no visible damage.

2) The resistance shall be measured between terminations a and c and the change in resistance compared with the value measured in Sub-clause 4.40.1 shall not exceed the limit specified in the relevant specification.

3) The terminal resistance shall be measured as specified in Sub-clause 4.7 and shall be less than the limit prescribed in the detail specification.

4) The insulation resistance shall be measured as specified in Sub-clause 4.13. The value shall not be less than that prescribed in the relevant specification.

5) The starting torque shall be measured as specified in Sub-clause 4.18 and shall be within the limits prescribed in the detail specification.

6) The continuity shall be tested as specified in Sub-clause 4.5 and the requirements of the detail specification shall be met.

7) The thrust and pull on the spindle shall be tested as specified in Sub-clauses 4.22.2 and 4.22.3 and the requirements of the detail specification shall be met.

8) The voltage proof test shall be carried out as specified in Sub-clause 4.12. There shall be no breakdown or flashover.

9) The rotational noise shall be measured as specified in Sub-clause 4.15 and shall not exceed the limit prescribed in the detail specification.

10) When applicable, the sealing test shall be performed as specified in Sub-clause 4.31 and the requirements of the detail specification shall be met.

4.41 A.C. endurance testing of mains switches on capacitive loads

This test, when required in the detail specification, shall be used to assess the electrical operation of mains switches used to switch from 45 to 65 Hz a.c. currents capacitive load.

4.41.1 Preparation of specimen

The test specimen shall be wired as specified in the detail specification and connected to the test circuit.

4.41.2 Test method

When specified in the detail specification, a load circuit as described below, shall be used for endurance tests for each pole pair in the case of a multipole switch. The correct electrical operation of each switch contact of multipole switches during the switch-off part of the operation cycle shall be monitored. Single pole switches should break the circuit between point J_1 and J_2 of the test circuit (see Fig. 34).

The switch shall be subjected to a total of 10 000 cycles of operation, unless otherwise specified in the detail specification. The duty cycle shall be approximately 50%. The rate of cycling shall be 7 to 12 cycles per minute.

In order to obtain random load conditions the switch closure shall not be synchronised to the supply frequency.

4.41.3 Test circuit

The test circuit shall be as given in Figure 34.

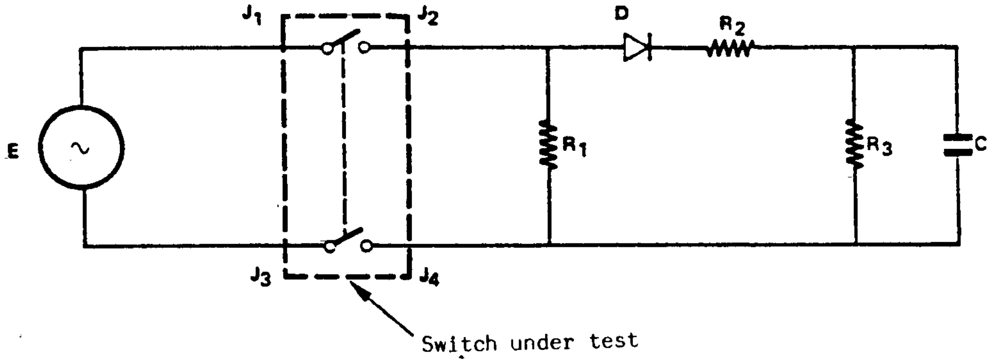


Fig. 34

where: E = r.m.s. voltage of the test source (45 to 65 Hz)

R_1 = 100 Ω or E/I where the rated current is specified

R_2 = 4.7 Ω

R_3 = 390 Ω

C = 390 µF

D = silicon diode having appropriate characteristics

When the surge current rating of the switch is specified, the following values shall be used:

R_1 = E/I, where E is the r.m.s. voltage of the test source, and I is the rated r.m.s. current

$$R_2 = \frac{R_1 \cdot \sqrt{2}}{X}$$, where X is the ratio of rated peak surge current to rated r.m.s. current

$$R_3 = \frac{800}{X} R_1$$

$R_2C = 2\,500 \times 10^{-6}$s

The load circuit components shall be such that the load current shall be within ± 10% of its specified value.

The impedance of the source shall be sufficiently low in order to not affect the test results.

4.41.4 Initial and final measurements

The contact resistance and temperature shall be measured before commencement of the test and on completion of the test.

Insulation resistance and voltage proof shall be measured on completion of the test.

4.41.5 Requirements

Contact resistance, insulation resistance and temperature rise shall be within specified limits.

There shall be no breakdown or flashover during application of the specified proof voltage.

4.41.6 Details to be specified

When this test is required by the detail specification, the following details shall be specified:

a) preparation of specimen;

b) voltage E to be applied;

c) test current (shall not be greater than the normal current rating of the specimen);

d) surge current (where known);

e) required number of cycles, if other than 10 000;

f) requirements for initial and final measurements;

g) additional requirements, if any.

4.42 D.C. endurance testing of switches

4.42.1 The switch shall be subjected to 5 000 operations at 10 to 17 cycles per minute, on/off, being loaded as given in Fig.35 and to further 5 000 operations without load.

During the 'off' part of the switching sequence, the switch contacts shall remain open for a period equal to or greater than 1 s.

After 10 000 operations (see Sub-clause 4.42.2) the switch shall be allowed to continue to operate up to the 25 000 operations required for the test of Sub-clause 4.40, but no further checks shall be made.

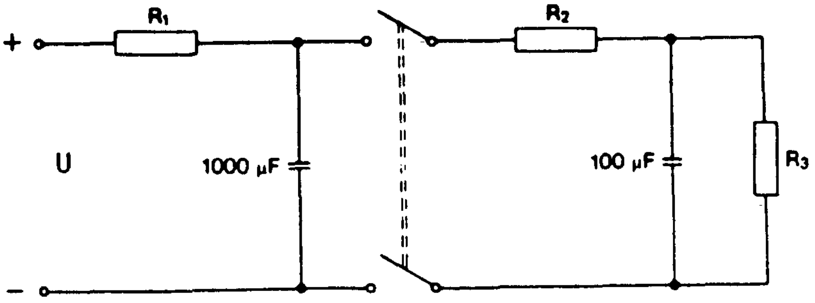


Fig. 35

Note. -When a single-pole switch is tested, it shall be connected in the positive line (between R_1 and R_2).

Switch application	Test voltage (V d.c.)	R_1 (Ω)	R_2 (Ω)	R_3 (Ω)
Power supply a.c.	225	⩽ 225	15	4 700
Power supply a.c./d.c.	225	⩽ 225	15	210
< 34 V	34	⩽ 34	6.8	33

Note. -Resistor R_1 shall be so chosen that the 1 000 uF capacitor shall be fully charged between each cycle of operation of the switch. The charging current shall be not greater than 1 A.

A cycle of operation is the closing of the switch contacts followed by their opening.

4.42.2 After 10 000 operations the following tests shall be made.

4.42.2.1 The switch shall be visually examined. There shall be no visible damage.

4.42.2.2 The torque required to operate the switch shall be measured as specified in Sub-clause 4.19 and shall not be greater than that specified in the detail specification.

4.42.2.3 The insulation resistance of the switch shall be measured as specified in Sub-clause 4.13. The value shall not be less than that prescribed in the relevant specification.

4.42.2.4 The switch contact resistance shall be measured as specified in Sub-clause 4.11 and shall be less than the value specified in the detail specification. The switch shall be operated with a load for between 5 and 10 operations and the correct electrical operation of each switch contact shall be monitored.

4.42.2.5 The voltage proof test shall be carried out on the switch as specified in Sub-clause 4.12. There shall be no breakdown or flashover.

4.43 Electrical endurance

The rated dissipation shall always be given with reference to an ambient temperature of 70 °C and shall be verified by means of the endurance test at 70 °C or, in the case of power potentiometers, the endurance test at room temperature using the correction factor given in Sub-clause 4.43.1.3.

When changes in the slope of the derating curve occur at temperatures other than 70 °C, one of the following procedures shall apply in addition to Sub-clauses 4.43.1 or 4.43.2.

1) At temperatures lower than 70 °C (e.g. when a potentiometer is derated linearly from 20 °C, through 70 °C, to zero dissipation at the upper category temperature or when a potentiometer has constant dissipation from 20 °C to 40 °C and then derates linearly from 40 °C, through 70 °C, to zero dissipation at the upper category temperature), the potentiometers shall be subjected to the conditions specified in Sub-clause 4.43.2 (electrical endurance at 70°C) except that:

   a) the test temperature shall be that at which the change in the slope of the derating curve occurs

   b) the voltage to be applied shall be the rated voltage multiplied by the correction factor, or it shall be the limiting element voltage, whichever is the smaller.

   This correction factor is:

$$\sqrt{\frac{\text{upper category temperature} - \text{test temperature}}{\text{upper category temperature} - 70\ ^\circ\text{C}}}$$

2) At temperatures higher than 70 °C (e.g. when a potentiometer maintains its rated dissipation constant from 20 °C, through 70 °C, to (say) 125 °C and then derates linearly to either zero dissipation or the category dissipation at the upper category temperature), the potentiometers shall be subjected to the conditions specified in Sub-clause 4.43.2 (electrical endurance at 70 °C) except that the test temperature shall be that at which the change in the slope of the derating curve occurs.

The requirements for intermediate and final measurements in 1) or 2) above shall be the same as those specified in the relevant specification for the endurance test used to verify the rated dissipation.

4.43.1 Electrical endurance at room temperature

4.43.1.1 The resistance between terminations a and c shall be measured. For those specimens which according to the relevant specification are to be loaded between terminations a and b or b and c the resistance shall also be measured between these terminations. (see Sub-clause 4.43.1.4)

4.43.1.2 The potentiometer shall be subjected to an electrical endurance test of 42 days (1 000 h) at an ambient temperature of 15 °C to 35 °C.

4.43.1.3 For potentiometers with a rated dissipation $\leqslant$ 10 W, the use of a d.c. voltage, provided the ripple does not exceed 5%, shall be the preferred method. If, however, it can be demonstrated that there will be no relaxation in the severity of the test, an a.c. voltage may be used. For potentiometers having a rated dissipation of $>$ 10 W an a.c. voltage shall be used.

The voltage to be applied for the purpose of this test shall be the voltage calculated from the rated resistance and 95% of the rated dissipation at 70 °C multiplied by the correction factor, or it shall be the limiting element voltage, whichever is the less.

The correction factor is:

$$\sqrt{\frac{\text{Zero dissipation temperature - test temperature}}{\text{Zero dissipation temperature - 70 °C}}}$$

The zero dissipation temperature shall be obtained from the derating curves in the relevant specification.

The applied voltage shall be within ± 5% of the calculated voltage.

4.43.1.4 During the test, the voltage shall be applied in cycles of 1.5 h on and 0.5 h off to half the specimens, between terminations a and c. For the remaining specimens, the moving contact shall be set at 95% (or 5% for potentiometers having inverse non-linear laws) of the total electrical travel and the voltage shall be applied in cycles of 1.5 h on and 0.5 h off to terminations a and b or b and c when appropriate.

Note. -The 0.5 h off periods are included in the total test duration specified in Sub-clause 4.43.1.2.

4.43.1.5 Unless otherwise specified (see Note), each potentiometer shall be mounted on a 1.5 mm thick steel panel having the dimensions given in the table below and placed in such a manner that the mounting point of any potentiometer is spaced, in any direction, from the mounting point of any other potentiometer by four times the diameter of the potentiometer.

The mounting point shall be the centre of the hole cut in the panel to accommodate the bush of the potentiometer.

Rated dissipation	Panel size in mm
Up to and including 4 W	50 x 50
Greater than 4 W up to and including 63 W	100 x 100
Greater than 63 W	300 x 300

Note. -Those potentiometers which are designed to be mounted by their terminations on printed boards shall be so mounted during this test on a 1.6 mm thick glass base epoxy-laminate board.

4.43.1.6 After approximately 48 h, 500 h and 1 000 h the potentiometers shall be removed from the test and allowed to cool under standard atmospheric conditions for testing for not less than one hour and not more than two hours.

After intermediate measurements the potentiometer shall be returned to the test. The interval between the removal from and the return to the test shall not exceed 12 h.

The potentiometers shall then be subjected to such of the following tests as are prescribed in the detail specification:

1) The potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.

2) The resistance shall be measured between terminations a and c and a and b or b and c as appropriate. The change in resistance with respect to the value measured in Sub-clause 4.43.1.1 shall not exceed the value prescribed in the relevant specification.

3) The insulation resistance shall be measured as specified in Sub-clause 4.13. The value shall not be less than that prescribed in the relevant specification.

4) The rotational noise shall be measured as specified in Sub-clause 4.15 and shall not exceed the limit prescribed in the detail specification.

5) The continuity shall be tested as specified in Sub-clause 4.5 and the requirements of the detail specification shall be met.

6) When applicable, the sealing test shall be performed as specified in Sub-clause 4.31 and the requirements of the detail specification shall be met.

4.43.2 Electrical endurance at 70 °C

4.43.2.1 The resistance between terminations a and c shall be measured. For those specimens which according to the relevant specification are to be loaded between terminations a and b (or b and c) the resistance shall also be measured between these terminations (see Sub-clause 4.43.2.4.).

4.43.2.2 The potentiometers shall be subjected to an electrical endurance test of 42 days (1 000 h) at an ambient temperature of 70 ± 3 °C.

4.43.2.3 For potentiometers with a rated dissipation of ⩽ 10 W the use of a d.c. voltage, provided the ripple does not exceed 5%, shall be the preferred method. If, however, it can be demonstrated that there will be no relaxation in the severity of test, an a.c. voltage may be used. For potentiometers having a rated dissipation of > 10 W an a.c. voltage shall be used.

The voltage to be applied for the purposes of this test shall be the rated voltage or the limiting element voltage, whichever is the less.

At all times during the test the applied voltage shall be within ± 5% of the calculated voltage.

4.43.2.4 During the test, the voltage shall be applied in cycles of 1.5 h on and 0.5 h off to half the specimens between terminations a and c. For the remaining specimens, the moving contact shall be set at 95% (or 5% for potentiometers having inverse non-linear laws) of the total electrical travel and the voltage shall be applied in cycles of 1.5 h on and 0.5 h off to terminations a and b or b and c when appropriate.

Note. -The 0.5 h off periods are included in the total test duration specified in Sub-clause 4.43.2.2.

4.43.2.5 Unless otherwise specified, the potentiometers shall be mounted as specified in Sub-clause 4.43.1.5.

The potentiometers shall not be heated by direct radiation and the circulation of the air in the chamber shall be adequate to prevent the temperature from departing by more than ± 3 °C from the nominal temperature of the chamber, at any point where potentiometers are placed.

4.43.2.6 After approximately 48 h, 500 h, and 1 000 h the potentiometers shall be removed from the chamber and allowed to cool under standard atmospheric conditions for testing for not less than one hour and not more than two hours.

After intermediate tests the potentiometers shall be returned to the test chamber. The interval between the removal of any potentiometer from the chamber and its return to the conditions of test shall not exceed 12 h.

The potentiometers shall then be subjected to such of the following tests as are prescribed for in the detail specification:

1) The potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.

2) The resistance shall be measured between terminations a and c, a and b or b and c as appropriate. The change in resistance with respect to the value measured in Sub-clause 4.43.2.1 shall not exceed the value prescribed in the relevant specification.

3) The insulation resistance shall be measured as specified in Sub-clause 4.13. The value shall not be less than that prescribed in the relevant specification.

4) The rotational noise shall be measured as specified in Sub-clause 4.15 and shall not exceed the limit prescribed in the detail specification.

5) The continuity shall be tested as specified in Sub-clause 4.5 and the requirements of the detail specification shall be met.

6) When applicable, the sealing test shall be performed as specified in Sub-clause 4.31 and the requirements of the detail specification shall be met.

4.43.3 Electrical endurance at upper category temperature

4.43.3.1 This test is not applicable to potentiometers having an upper category temperature of 70 °C.

4.43.3.2 The resistance between terminations a and c shall be measured. For those specimens which according to the relevant specification are to be loaded between terminations a and b or b and c the resistance shall also be measured between these terminations (see Sub-clause 4.43.3.5).

4.43.3.3 The potentiometers shall be subjected to an electrical endurance test of 42 days (1 000 h) at the upper category temperature ± 3 °C given in the relevant specification.

4.43.3.4 For those potentiometers derating to zero at their upper category temperature, the test shall be performed at zero dissipation. For other potentiometers the test shall be performed with their category dissipation. For potentiometers having a rated dissipation $\leqslant 10$ W the use of a d.c. voltage, provided the ripple does not exceed 5%, shall be the preferred method. If, however, it can be demonstrated that there will be no relaxation in the severity of the test, an a.c. voltage may be used. For potentiometers having a rated dissipation > 10 W an a.c. voltage shall be used.

The voltage shall be the limiting element voltage, or that voltage calculated from the category dissipation and the rated resistance, whichever is the less.

At all times during the test the applied voltage shall be within ± 5% of the calculated voltage.

4.43.3.5 During the test, the voltage shall be applied in cycles of 1.5 h on and 0.5 h off to half the specimens between terminations a and c. For the remaining specimens, the moving contact shall be set at 95% (or 5% for potentiometers having inverse non-linear laws) of the total electrical travel and the voltage shall be applied in cycles of 1.5 h on and 0.5 h off to terminations a and b or b and c when appropriate.

Note. -The 0.5 h off periods are included in the total test duration specified in Sub-clause 4.43.3.3.

4.43.3.6 Unless otherwise specified, the potentiometers shall be mounted as specified in Sub-clause 4.43.1.5.

The potentiometers shall not be heated by direct radiation and the circulation of the air in the chamber shall be adequate to prevent the temperature from departing by more than ± 3 °C from the nominal temperature of the chamber, at any point where potentiometers are placed.

4.43.3.7 After approximately 48 h, 500 h and 1 000 h the potentiometers shall be removed from the chamber and allowed to cool under standard atmospheric conditions for testing for not less than one hour and not more than two hours.

After intermediate measurements the potentiometers shall be returned to the test chamber. The interval between the removal of any potentiometer from the chamber and its return to the test shall not exceed 12 h.

The potentiometer shall than be subjected so such of the following tests as are called for in the detail specification.

1) The potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.

2) The resistance shall be measured between terminations a and c, a and b or b and c as appropriate. The change in resistance with respect to the value measured in Sub-clause 4.43.3.2 shall not exceed the value prescribed in the relevant specification.

3) The insulation resistance shall be measured as specified in Sub-clause 4.13. The value shall not be less than that prescribed in the relevant specification.

4.44 Component solvent resistance

4.44.1 Initial measurements

The measurements prescribed in the relevant specification shall be made.

4.44.2 The components shall be subjected to Test XA of IEC 68-2-45, with the following details:

a) Solvent to be used:	See Sub-clause 3.1.1 of IEC 68-2-45.
b) Solvent temperature:	23 ± 5 °C, unless otherwise specified in the detail specification.
c) Conditioning:	Method 2, (without rubbing).
d) Recovery time:	48 h, unless otherwise stated in the detail specification.

4.44.3 The measurements prescribed in the relevant specification shall then be made and the specified requirements be met.

4.45 Solvent resistance of the marking

4.45.1 The components shall be subjected to Test XA of IEC 68-2-45, with the following details:

a) Solvent to be used:	See Sub-clause 3.1.1 of IEC 68-2-45.
b) Solvent temperature:	23 ± 5 °C.
c) Conditioning:	Method 1 (with rubbing).
d) Rubbing material:	Cotton wool.
e) Recovery time:	Not applicable, unless otherwise stated in the detail specification.

4.45.2 After the test the marking shall be legible.

APPENDIX A

RULES FOR THE PREPARATION OF DETAIL SPECIFICATIONS FOR CAPACITORS AND RESISTORS FOR ELECTRONIC EQUIPMENT

1. The drafting of a complete detail specification by IEC Technical Committee No. 40: Capacitors and Resistors for Electronic Equipment, if required, shall begin only when all the following conditions have been met:

   a) the generic specification has been approved;

   b) the sectional specification, when appropriate, has been circulated for approval under the Six Months' Rule;

   c) the associated blank detail specification has been circulated for approval under the Six Months' Rule;

   d) there is evidence that at least three National Committees have formally approved, as their own national standard, specifications covering a component of closely similar performance.

   Where a National Committee formally asserts that substantial or significant use is made within its country of a part described by some other national standard, this assertion may count towards the foregoing requirement.

2. Detail specifications prepared under the responsibilily of Technical Committee No. 40, shall use the standard or preferred values, rating and characteristics and severities for environmental tests, etc., which are given in the appropriate generic or sectional specifications.

   An exception to this rule may only be granted for a specification when agreed by Technical Committee No. 40.

3. The detail specification should not be circulated under the Six Months' Rule until the sectional and blank detail specifications have been approved for publication.

APPENDIX B

INTERPRETATION OF SAMPLING PLANS AND PROCEDURES AS DESCRIBED IN IEC PUBLICATION 410 FOR USE WITHIN THE IEC QUALITY ASSESSMENT SYSTEM FOR ELECTRONIC COMPONENTS

When using IEC Publication 410 (1973) for inspection by attributes the following interpretations of the clauses indicated below apply for the purpose of this Standard:

1.1 The responsible authority is the National Authorized Institution implementing the Basic Rules and Rules of Procedure.

1.5 The unit of product is the electronic component defined in a detail specification.

2 Only the following definitions from this clause are required:

- a defect is any non-conformance of the unit of product to specified requirements.

- a defective is a unit of product which contains one or more defects.

3.1 The extent of non-conformance of product shall be expressed in terms of percent defective.

3.3 Not applicable.

4.5 The responsible authority is the IEC Technical Committee drafting the blank detail specification which forms part of the generic or sectional document.

5.4 The responsible authority is the Chief Inspector, acting in accordance with the procedures prescribed in the document describing the inspection department of the approved manufacturer and approved by the National Supervising Inspectorate.

6.2 The responsible authority is the Chief Inspector.

6.3 Not applicable.

6.4 The responsible authority is the Chief Inspector.

8.1 Normal inspection shall always be used at the start of inspection.

8.3.3 (d) The responsible authority is the Chief Inspector.

8.4 The responsible authority is the National Supervising Inspectorate.

9.2 The responsible authority is the IEC Technical Committee drafting the blank detail specification which forms part of the generic or sectional document.

9.4 (Fourth sentence only) Not applicable.
(Fifth sentence only) The responsible authority is the Chief Inspector.

10.2 Not applicable.

APPENDIX C

A SUITABLE METHOD FOR MEASURING ROTATIONAL NOISE, METHOD A

The circuit of the apparatus for measuring the rotational noise of potentiometers is shown in Figure 36.

Basically, the apparatus is an audio amplifier of adjustable gain feeding a diode rectifier which controls a coloured lamp. When the signal input reaches some pre-determined level the coloured lamp is illuminated.

This is used to indicate that the noise output of a potentiometer is above or below some pre-set limit level. The apparatus is arranged to provide 20 V d.c. with a source resistance of 1 000 ohms to apply to the potentiometer.

The following data are given on the response of the amplifier:

- 6 dB below zero level at 60 Hz and 20 kHz;
- 20 dB below zero level at 20 Hz and 45 kHz;
- 30 dB or more below zero at 80 kHz and all higher frequencies;
- zero level is taken at 1 000 Hz.

The preset input levels at approximately 1 000 Hz which operate the red lamp are:

4.7 - 6.8 - 10 - 15 - 22 - 33 - 47 - 68 - 100 - 150 - 220 mV r.m.s.

If the amplifier has a too extended bass response, it is possible that, when testing Law B and Law C potentiometers, harmonics of the 0.5 Hz operating frequency may give rise to appreciable error in the noise reading on very low-noise potentiometers. To avoid this, the amplifier shall be designed so that it cuts off rapidly below 50 Hz.

The circuit shall ensure that short noise durations will cause the red lamp to operate long enough to be observed.

A second circuit operates at about one-tenth of the pre-set level and illuminates a green light. Since it is unlikely that potentiometers will be found with a noise level less than one-tenth of the limit, the green lamp will operate on good potentiometers and the red lamp on reject potentiometers.

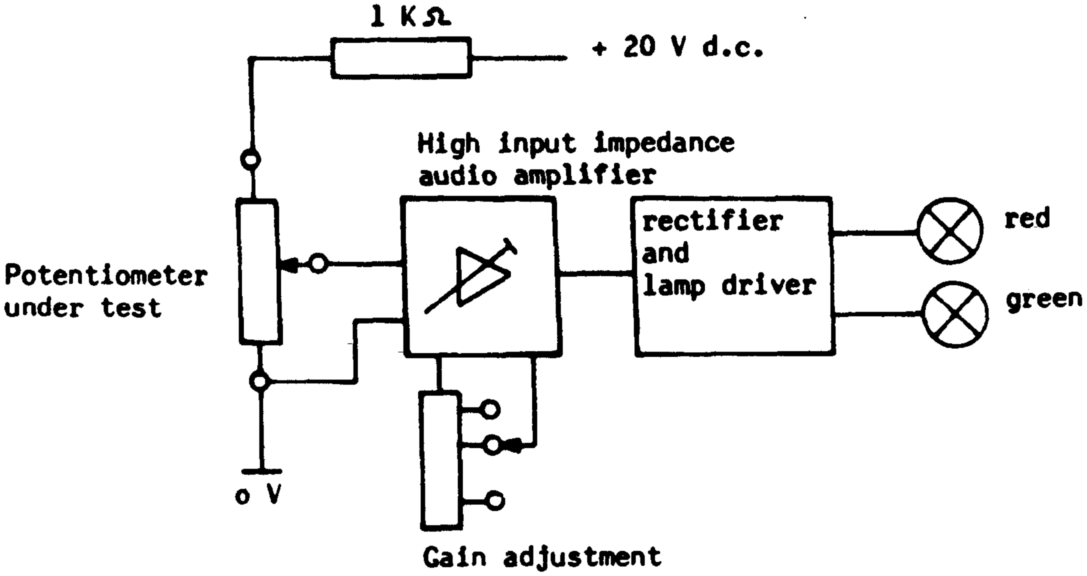


Fig. 36- Circuit for measurement of rotational noise, Method A.

APPENDIX D

APPARATUS FOR MEASURING MECHANICAL ACCURACY

D1. Dial indicator

D1.1 The minimum dial division shall be equal to or less than 10% of the specified tolerance and shall have a readability to 1 µm for measurements of less than 25 µm. The indicator should not be used over a range of more than a third of the total travel of the probe without error correction. If a dial indicator is used with a pivot type pointer, the longitudinal centre line of the stylus shall remain normal to the relevant part of the potentiometer during measurement or the applicable correction factor shall be used.

The dial indicator holding fixture shall hold the dial indicator rigidly maintaining its proper attitude to the workpiece during measurement.

In addition, it should provide for a gradual movement of the indicator position so that it is not damaged as the probe approaches the potentiometer.

D2 Cylindrical spindle adaptor

An adaptor with a smooth cylindrical surface and which, when mounted on the potentiometer spindle, adds eccentricity no greater than 10% of the specified run-out tolerance.

D3 Potentiometer mounting fixture

A fixture to hold the test specimen rigidly by the normal mounting means leaving the spindle free to move.

D4 Potentiometer spindle holding fixture

A fixture to hold the test specimen by the spindle in either a horizontal or vertical position leaving the potentiometer body free to move.

AMENDMENT NO. 1

Page 7

2.2.19.2 Temperature coefficient of resistance (α)

Replace in the title and in the formula "α" by "α_R"

Add a new Sub-clause 2.2.19.3:

2.2.19.3 Temperature coefficient of output ratio (α_o)

The relative variation of voltage output ratio between two given temperatures (mean coefficient) at fixed values of setting and load of the moving contact, divided by the difference in temperature producing it. It shall be preferably be expressed in parts per million per °C.

$$\alpha_o = \frac{(U_{ab2}/U_{ac2}) - (U_{ab1}/U_{ac1})}{(U_{ab1}/U_{ac1}) \times \Delta\theta}$$

where $\Delta\theta$ is the algebraic difference, in degrees Celsius, between the reference temperature and the specified ambient temperture.

Notes 1. -The value of α_o may be different for different setting of the output ratio.

2. -It should be noted that the use of the term does not imply that the function exhibits any degree of linearity, nor should any be assumed.

2.2.24 Ganged potentiometer

Add at the end the following sentence:

"The number of sections shall be included in the description, e.g. 2-ganged potentiometer or 4-ganged potentiometer".

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2.2.25 Dual potentiometers

Amend the title to read: "Dual concentric potentiometers".

Page 23

Add the following new definitions:

2.2.49.30 Microlinearity

The relative change of linearity deviation (see "Independent Linearity") measured for small travel increments and expressed as a percentage of the applied voltage.

2.2.50 Rotary potentiometer (single-turn or multi-turn)

A potentiometer which is actuated by an axial spindle perpendicular to the direction of rotation, and may be operated frequently to adjust voltage or resistance values.

2.2.51 Power potentiometer

A potentiometer having a resistive element which is designed and constructed for high internal temperature rise and heat transfer capability.

2.2.52 Precision potentiometer

A potentiometer in which the output voltage or resistance law meets a precisely defined law as a function of the position of the actuating device.

2.2.53 Slide potentiometer

A potentiometer which is actuated by a rectilinear movement of an actuator and may be operated frequently to adjust voltage or resistance values.

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Replace the existing Sub-clause 4.11 by:

4.11 Switch contact resistance (when appropriate)

Note. -The tests given in this Sub-clause are identical to Tests 2a and 2b respectively, of IEC Publication 512-2 (1976).

4.11.1. Contact resistance - Millivolt level method

4.11.1.1 Object

The object of this test is to detail a standard method to measure the electrical resistance across a pair of mated contacts or a contact with a measuring gauge.

4.11.1.2 General measuring requirements

Measurements may be carried out with direct current or alternating current. For a.c. measurements, the frequency shall not exceed 2 kHz. In the case of dispute, the d.c. measurement shall govern.

The accuracy of the measuring apparatus shall be such that the total error does not exceed 10 %.

4.11.1.3 Method of measurement

4.11.1.3.1 Measurement details

The contact resistance shall be derived normally from the voltage drop measured between the zones intended for connection of the wiring to the contacts at the points specified in the detail specification.

The contact shall not be operated while the measuring voltage is applied.

Care must be taken during the measurement to avoid exerting abnormal pressure on the contacts under test and to avoid movement of the test cables.

Where the connection points specified in the detail specification are not directly accessible, the resistance of the cable or wire used shall be subtracted from the measured value. The corrected value shall be recorded.

The contacts to be measured shall be chosen in accordance with the detail specification.

4.11.1.3.2 Test current and voltage

In order to prevent the breakdown of insulating films on the contacts, the e.m.f. of the measuring circuit shall not exceed 20 mV d.c. or a.c. peak, open circuit.

The test current shall not exceed 100 mA, a.c. or d.c.

4.11.1.4 Measurements

4.11.1.4.1 Measurement with direct current

The measuring cycle consists of:

a) making the contact;
b) application of the voltage;
c) measurement with current flowing in one direction;
d) measurement with current flowing in the opposite direction;
e) disconnection of the voltage source;
f) breaking the contact.

4.11.1.4.2 Measurement with alternating current

The measuring cycle consists of:

a) making the contact;
b) application of the voltage;
c) making the measurement;
d) disconnection of the voltage source;
e) breaking the contact.

4.11.1.5 Requirements

The value of the contact resistance shall not exceed the value specified in the detail specification.

The contact resistance measurement with d.c. shall be the average of the two readings obtained with forward and reverse current.

Note. -Any deviation from the standard test procedure should be clearly indicated in the test report.

4.11.1.6 Details to be specified

When this test is required by the detail specification, the following details shall be specified:

a) the connecting point of the measuring wires, their type and size, if applicable;
b) for mated sets, the contacts to be measured and the number of measuring cycles;
c) for individual mated contacts, the number of contacts to be measured;
d) whether contacts are to be operated before the measurements and/or between the measuring cycles;
e) the permissible limits of contact resistance;
f) any deviation from the standard test method and/or conditions.

4.11.2 Contact resistance - Specified test current method

4.11.2.1 Object

The object of this test is to detail a standard method to measure the electrical resistance across a pair of mated contacts or a contact with a measuring gauge.

4.11.2.2 General measuring requirements

Measurements may be carried out with direct current or alternating current. For a.c. measurements, the frequency shall not exceed 2 kHz. In the case of dispute, the d.c. measurements shall govern.

The accuracy of the measuring apparatus shall be such that the total error does not exceed 10 %.

4.11.2.3 Method of measurement

4.11.2.3.1 Measurement details

The contact resistance shall be derived normally from the voltage drop measured between the zones intended for connection of the wiring to the contacts at the points specified in the detail specification.

The contact shall not be operated while the measuring voltage is applied.

Care must be taken during the measurement to avoid exerting abnormal pressure on the contacts under test and to avoid movement of the test cables.

Where the connection points specified in the detail specification are not directly accessible, the resistance of the cable or wire used shall be subtracted from the measured value.
The corrected value shall be recorded.

The contacts to be measured shall be chosen in accordance with the detail specification.

4.11.2.3.2 Test current and voltage

The contact resistance shall be measured with the rated alternating current or direct current as specified in the detail specification. The e.m.f. of the source shall not exceed 60 V d.c. or a.c. peak, but shall be at least 1 V, as specified in the detail specification.

Measurements shall be made on individual contacts within the minute following application of the test current.

4.11.2.4. Measurements

4.11.2.4.1 Measurement with direct current

The measuring cycle consists of:

a) making the contact;
b) application of the voltage;
c) measurement with current flowing in one direction;
d) measurement with current flowing in the opposite direction;
e) disconnection of the voltage source;
f) breaking the contact.

Note. -Unless otherwise specified, the made contacts should not be disturbed between the end of a preceding test and the application of the voltage in this test, nor between successive measuring cycles.

4.11.2.4.2 Measurement with alternating current

The measuring cycle consists of:

a) making the contact;
b) application of the voltage;
c) making the measurement;
d) disconnection of the voltage source;
e) breaking the contact.

Note. -Unless otherwise specified, the made contacts should not be disturbed between the end of a preceding test and the application of the voltage in this test, nor between successive measuring cycles.

4.11.2.5 Requirements

The value of the contact resistance shall not exceed for any measurement the value specified in the detail specification.

The contact resistance measurement with d.c. shall be the average of the two readings obtained with forward and reverse current.

Note. -Any deviation from the standard test procedure should be clearly indicated in the test report.

4.11.2.6 Details to be specified

When this test is required by the detail specification, the following details shall be specified:

a) the connecting point of the measuring wires, their type and size, if applicable;

b) for mated sets, the contacts to be measured and the number of measuring cycles;

c) for individual mated contacts, the number of contacts to be measured;

d) whether contacts are to be operated before the measurements and/or between the measuring cycles;

e) the measuring current;

f) the permissible limits of contact resistance;

g) any deviation from the standard test method and/or conditions.

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Add a new Sub-clause 4.14.5:

4.14.5 Temperature coefficient of output ratio (α_o)

4.14.5.1 The potentiometer shall be dried as specified in Sub-clause 4.14.1. The moving contact shall be set to the position prescribed in the relevant specification and locked in a suitable manner to eliminate changes of setting which may be caused by mechanical and/or thermal influences. The detail specification may specify a load to be applied to the moving contact termination.

4.14.5.2 The potentiometer shall successively be maintained at each of the temperatures specified according to Sub-clause 4.14.2. The total resistance or a suitable other characteristic shall be monitored in order to judge whether thermal stability has been reached in each step.

4.14.5.3 The output ratio (or, if the input voltage is sufficiently stable, the output voltage) shall be measured at each of the temperatures specified in Sub-clause 4.14.5.2 after the potentiometer has reached thermal stability.

The temperature of the test chamber at the time of output ratio measurement shall be recorded. The error in the measurement of the temperature shall not exceed 1 °C.

The condition of thermal stability may be judged to be reached when two readings of total resistance taken at an interval of not less than 5 min do not differ by an amount greater than that which can be attributed to the measuring apparatus.

4.14.5.4 The temperature coefficient of output ratio between 20 °C and each of the other temperatures specified in Sub-clause 4.14.5.2 shall be calculated from the following formula:

$$\alpha_o = \frac{\Delta(U_{ab}/U_{ac})}{(U_{ab}/U_{ac}) \times \Delta\theta} \times 10^6 \text{ (in } 10^{-6}/{}^\circ\text{C)}$$

where (U_{ab}/U_{ac}) is the output ratio at the reference temperature and $\Delta(U_{ab}/U_{ac})$ is the algebraic difference of voltage, in volt, between the reference temperature and the specified ambient temperature.

If the values of output ratio recorded in Sub-clause 4.14.5.3 are designated in the same way as are the resistance values of Sub-clause 4.14.4, the values of (U_{ac}/U_{ab}) and of $\Delta(U_{ab}/U_{ac})$ correspond to the table in Sub-clause 4.14.4 with R replaced by (U_{ab}/U_{ac}).

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4.28.2.1 Replace the first sentence by:

"The control spindle shall be oscillated at the rate of 55 ± 10 Hz through an angle of between 5° and 10°."

Add after the first sentence, a new sentence as follows:

"The positions of both points of reversal of motion, as given in the detail specification, shall be stable within 1° throughout the test period."

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4.40.4 Replace the existing text by:

A suitable driving mechanism shall be fixed to the control spindle and arranged to operate cyclicly so that the mechanical travel is according to one of the following methods:

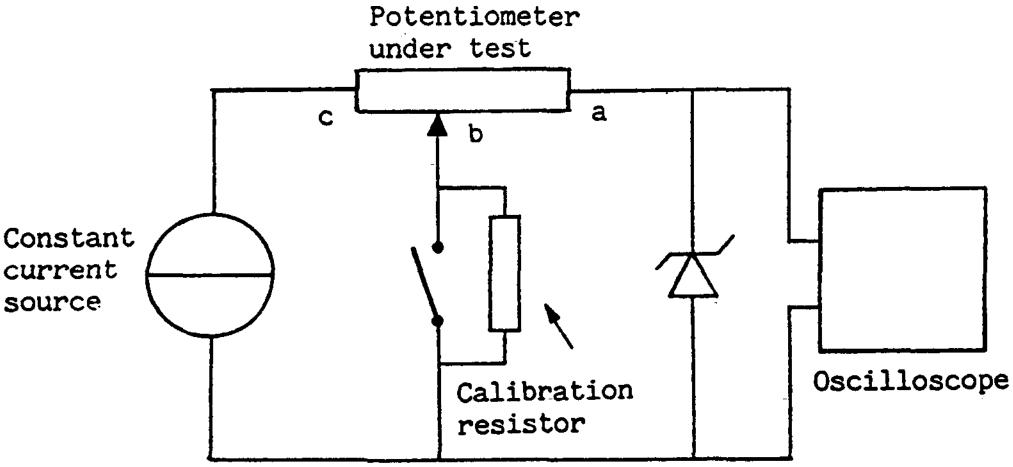
Method 1: greater than 90 % of the total mechanical travel. (This method is to be used unless otherwise specified in the relevant specification).

Method 2: 50 ± 5 % of the effective electrical travel. (This method is preferred for precision potentiometers and shall be specified in the relevant specification).

The torque of the driving mechanism shall not be more than 200 mN.m for potentiometers with a rated dissipation not exceeding 10 W and not more han 714 mN.m for potentiometers exceeding 10 W rated dissipation.

4.40.6 Add at the end a new item 11 as follows:

11) When continuous monitoring of the contact resistance is specified during the mechanical endurance test, the following procedure shall be used:



A constant current of $\frac{0{,}01\ \text{V}}{\text{Rated resistance}}$ ± 5 %, or as specified in the detail specification, shall be applied between terminations b and c. The signal on the moving contact shall be monitored during mechanical cycling for continuity throughout the test. Discontinuity shall be considered to have occurred if the resistance of the moving contact rises to more than 10 times the rated total resistance for more than 0,1 % of the distance specified in Methods 1 or 2 of Sub-clause 4.40.4 as applicable, unless otherwise specified in the detail specification.

Add at the end a new item 12 as follows:

12) The conformity (linearity or other specified law) shall be tested as specified in Sub-clause 4.9 and shall meet the requirements of the detail specification.

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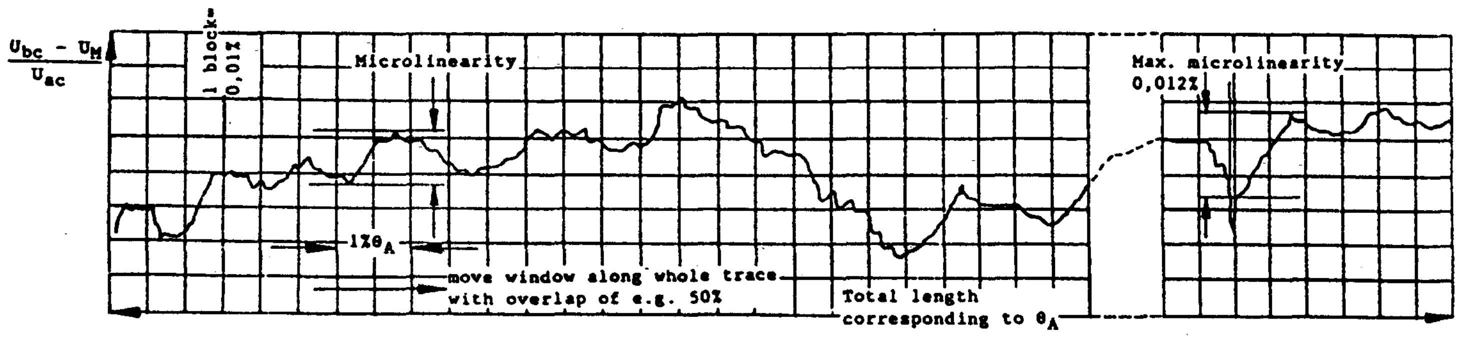
Add the following new measuring method:

4.46 Microlinearity

4.46.1 Microlinearity shall be measured with a maximum load of 1 µA on the moving contact termination b of the potentiometer under test. Effects of non-uniform speed of travel shall be excluded.

The value of microlinearity is equal to the change of linearity along the travel increment at any measured position (see Figure 1). The measurement increments shall have an overlap of not less than 50 %. The measurement principle is given in Figure 2.



θ_A = effective electrical travel

Figure 1 - Example of microlinearity measurement

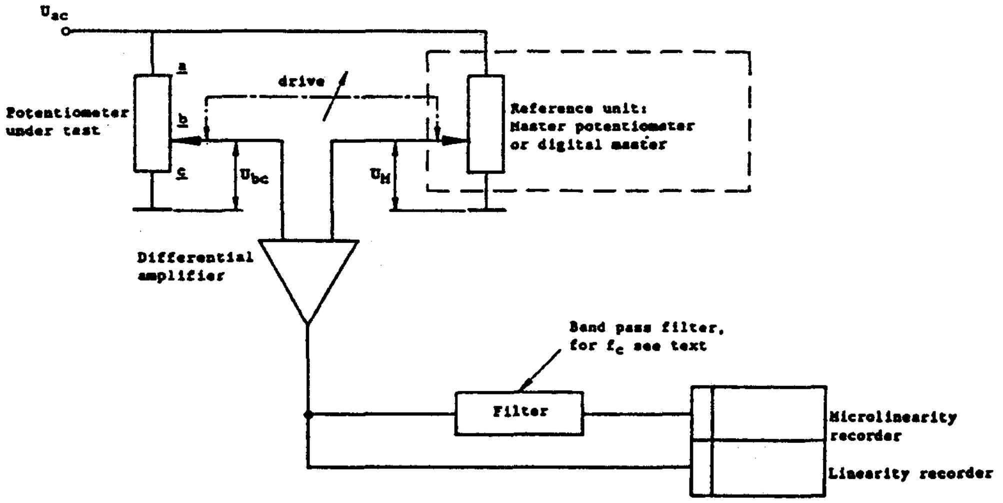
4.46.2 The detail specification shall specify:

a) The increment if different from 1 % of the effective electrical travel.

b) The part of the electrical travel to be covered, if different from the effective electrical travel.

c) The requirement of microlinearity. The requirement may differ for different parts of the electrical travel.

A practical example of a test circuit and results is given below.



Note. -For the digital reference unit, the basic description is given in Appendix E.

Figure 2 - Block diagram of a circuit for evaluation of microlinearity

The filter shown in Figure 2 is a band pass filter which shall pass all frequencies from the lower cut-off frequency f_c to 100 f_c. The purpose of the filter is to remove slow voltage variations caused by the potentiometer law and by voltage instability.

f_c shall be calculated as follows:

$f_c = m/(i \times t_m)$, where
i = increment, in millimeters;
m = effective electrical travel, in millimeters;
t_m = time for traverse of m, in seconds.

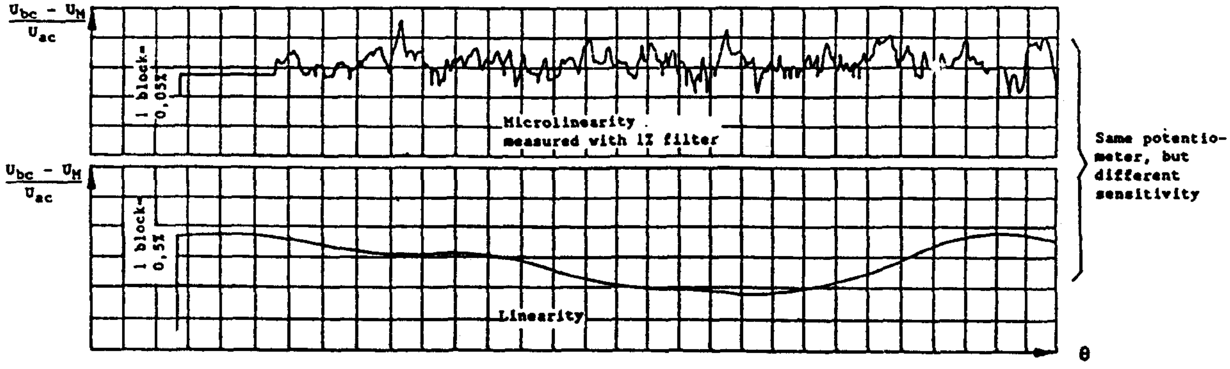


Figure 3 - Example of simultaneous evaluation of linearity and microlinearity

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- Add the new APPENDIX E:

APPENDIX E

MEASURING METHOD FOR MICROLINEARITY

Basic description of a digital reference unit (synthetic high precision master unit) and measuring method for microlinearity.

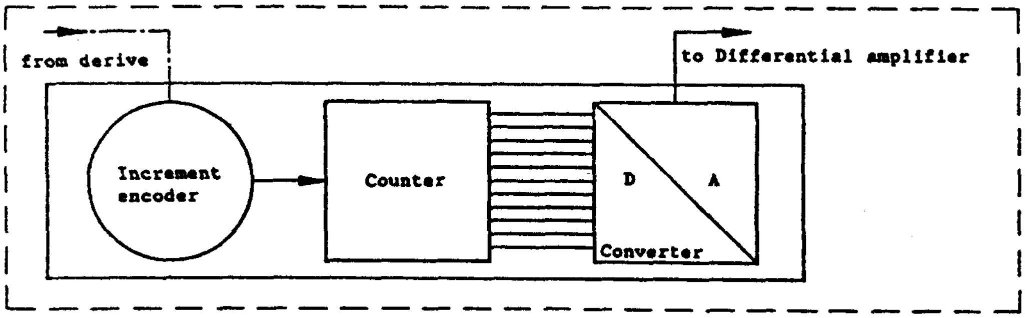

Figure 4 - Block diagram of a digital reference unit (synthetic high precision master)

When selecting a suitable DA converter for the synthetic master reference unit of Figure 4, the following basic details should be considered:

(1) - Resolution bits

The minimum number of bits (b) which should be covered by the DA converter shall be the greater of b_v and b_i calculated as below.

The number b_v of bits required for voltage accuracy is

$b_v = (1/\ln 2) \times \ln(5/\mu_{max})$, where

μ_{max} = maximum allowed microlinearity (1 % = 0,01);
$1/\ln 2$ = 1,443.

The number of bits b_i required by the relative travel increment width as specified for the measurement is:

$$b_i = (1/\ln 2) \times \ln(30m/i), \text{ where}$$

$$\left.\begin{array}{ll} i & = \text{width of increment;} \\ m & = \text{effective electrical travel;} \\ 1/\ln 2 & = 1{,}443. \end{array}\right\} \text{ in identical units}$$

(2) - Accuracy of the DA converter output

Minimum requirement 1/2 last significant bit (LSB). With b chosen as under (1) above, the resulting digital synthetic master will have a voltage setting accuracy of ten times better as is required for the measurement.

(3) - Maximum measuring speed

The measuring speed shall consider the setting time of the DA converte and should at least allow for twice the sum of all setting times involved. Hence the minimum time t_m required for one measuring travel becomes:

$$t_m = 2^b \times 2t_s, \text{ where}$$

t_s = setting time of the DA converter;
b = number of bits covered by travel.

Example - Requirement for voltage accuracy : 0,03 %
relative increment i/m: 1 %

Result: $b_v = 1{,}443 \times \ln(5/0{,}0003) = 14{,}03$; $b_v = 14$ bit;
$b_i = 1{,}443 \times \ln(30/0{,}01) = 11{,}55$; $b_i = 12$ bit;

The voltage bit figure is the higher one; i.e.:
The DA converter shall be at least of a 14 bit type, able to simulate a master potentiometer with the usual ten times better accuracy as compared to the deviations to be measured.

(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 68-2-6 (1970) Test Fc : Vibration (sinusoidal)	IS 9000 (Part 8) : 1981 Part 8 Vibration (sinusoidal) test	Not Equivalent
IEC 68-2-13 (1966) Test M : Low air pressure	IS 9000 (Part 13) : 1981 Part 13 Low air pressure test	do
IEC 68-2-14 (1974) Test N : Change of temperature	IS 9000 (Part 14/Sec 1) : 1988 Part 14 Test N Change of temperatue, Section 1 Test Na : Rapid change of temperature (thermal shock) with prescribed time of transition — Two chamber method	do
IEC 68-2-17 (1968) Test Q : Sealing	IS 9000 (Part 15/Sec 1) : 1982 Part 15 Sealing test, Section 1 General	do
IEC 68-2-20 (1979) Test T : Soldering	IS 9000 (Part 18/Sec 1) : Part 18 Solderability test, Section 1 Solderability of wire and tag terminations	do
IEC 68-2-21 (1983) Test U : Robustness of terminations and integral mounting devices	IS 9000 (Part 19/Sec 1) : 1986 Part 19 Test U, Robustness of terminations and integral mount devices, Section 1 Test Ua1 : Tensile	do
IEC 68-2-27 (1972) Test Ea : Shock	IS 9000 (Part 7/Sec 1) : 1979 Part 7 Impact test, Section 1 Shock	do
IEC 68-2-29 (1968) Test Eb : Bump	IS 9000 (Part 7/Sec 2) : 1979 Part 7 Impact test, Section 2 Bump	do
IEC 68-2-30 (1980) Test Db : Damp heat, cyclic (12+12-hours cycle)	IS 9000 (Part 5/Sec 2) : 1981 Part 5 Damp heat (cyclic) test, Section 2 12+12 h cycle	do
IEC 68-2-45 (1980) Test XA and guidance : Immersion in cleaning solvents	IS 9000 (Part 20) : 1979 Part 20 Resistance to cleaning solvents and permanence of markings	do
IEC 117 Recommended graphical symbols	IS 2032 Graphical symbols used in electrotechnology	do
IEC 410 (1973) Sampling plans and procedures for inspection by attributes	IS 10673 : 1983 Sampling plans and procedures for inspection by attributes for electronic items	do
IEC QC 001001 (1986) Basic rules for the IEC quality assessment system for electronic components (IECQ)	IS QC 001001 : 1988 Basic rules for the IEC quality assessment system for electronic components (IECQ)	Identical
IEC QC 001002 (1986) Rules of procedure for the IEC quality assessment system for electronic components (IECQ)	IS QC 001002 : 1988 Rules of procedure for the IEC quality assessment system for electronic components (IECQ)	do
ISO 3 (1973) Preferred numbers — Series of preferred numbers	IS 1076 (Part 1) : 1985 Preferred numbers : Part 1 Series of preferred numbers	do
ISO 497 (1973) Guide to the series of preferred numbers and of series containing more rounded values of preferred numbers	IS 1076 (Part 3) : 1985 Preferred numbers : Part 3 Guide to the series of preferred numbers and of series containing more rounded values of preferred numbers	do
ISO 1000 (1973) SI units and recommendations for the use of their multiples and of certain other units	IS 10005 : 1994 SI units and recommendations for the use of their multiples and of certain other units	do

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following international standard and has decided that it is acceptable for use in conjunction with this standard :

IEC 390 (1972) Dimensions of spindle ends for manually operated electronic components

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This Indian Standard has been developed from Doc : No. LTD 14 (1388).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at New India Printing Press, Khurja, India